DISEASES AND PESTS OF THE RUBBER TREE

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DISEASES AND PESTS
OF
THE RUBBER TREE

BY

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MACMILLAN AND CO., LIMITED
ST. MARTIN'S STREET, LONDON
1936

PRINTED IN GREAT BRITAIN
BY R. & R. CLARK, LIMITED, EDINBURGH

PREFACE

THE results obtained since 1931 at the Pathological Division, Rubber Research Institute, Malaya, and elsewhere have proved of such outstanding importance that a permanent record becomes very desirable. The Institute has passed through more than one critical period in recent years, but despite the fact that administrative troubles caused considerable concern during the period 1931–34, credit is due to those members of the staff who maintained the closest interest in the scientific problems on which they were engaged. In the pathological division continuous progress was maintained. The same remarks can be applied to other divisions in the Institute, and in this particular instance, a tribute to the detached attitude by scientific workers towards administrative troubles, is well deserved.

My acknowledgments are due to the many authors whose works have been consulted. Extensive use has been made of the two most important works written on the diseases of the rubber tree, namely, *The Diseases and Pests of the Rubber Tree* (T. Petch, 1921) and *Diseases and Pests of Hevea brasiliensis* (Dr. A. Steinmann, 1925). With reference to insect pests, I am indebted mainly to *The Agricultural Zoology of the Malaya Archipelago*, by Dr. K. W. Dammermann. Further, I have made considerable use of *Diseases of Crop Plants in the Lesser Antilles*, by W. Nowell, published by the West India Committee, and I have obtained valuable aid from *Fungi and Disease in Plants*, by Dr. E. J. Butler, F.R.S., 1918. Again, I have to mention my indebtedness to the evergreen *Text Book of Botany*, by Strasburger, in respect of Part II, and also to the work, by W. C. Stevens, entitled *Plant Anatomy*, 1924. Short extracts have also been taken from *Fungus Diseases of Plants*, by B. M. Duggar, 1909. No attempt has been made to make alterations in the written text of portions taken from other books if the extracts adequately meet the case. It is thought that much useless repetition has been saved by adopting this procedure, while any improvement could scarcely be anticipated. Full references to other works consulted will be found in the text.

It is not an easy matter to make full acknowledgment to all past and present colleagues who have willingly assisted me with the latest information in their respective lines of work. I am greatly indebted to Mr. R. P. N. Napper, for I have utilised his recent reports on root-

disease problems to the full. The same applies to the work of Mr. F. Beeley in connection with work on *Oidium* leaf-fall disease and also with reference to incidental problems such as the treatment of white-ant attacks, of mouldy-rot control, and in connection with the latter, in the preparation of a White List of proprietary compounds possessing fungicidal properties, which have passed the required tests successfully.

It is desirable at this stage to mention the work carried out by colleagues in the Department of Agriculture, Straits Settlements and Federated Malay States. To Mr. W. N. C. Belgrave, the present Chief Research Officer in the Department, full tribute must be paid for his unfailing help when abstruse aspects of disease problems required discussion. His own personal contributions on disease problems in rubber plantations, such as the work on red root disease and on the various panel diseases, is well known. I am also indebted for aid and collaboration from Mr. F. W. South. The work of my successor to the post of Government Mycologist, Mr. A. Thompson, on the various "Phytophthoraceous" fungi found affecting rubber trees is worthy of mention, and his publication has proved to be of great use in leading to a correct presentation of this intricate subject. I wish also to record my indebtedness to Mr. G. H. Corbett, Government Entomologist, Department of Agriculture, S.S. & F.M.S., both for supplying information and for personal help in many entomological problems which have appeared during my three years as head of the Pathological Division of the Rubber Research Institute. The Institute has no specialist officer in entomology attached to the staff, and this branch has had therefore to be dealt with by the Pathological division as far as possible. Information on *Psilopholis grandis* was due almost entirely to Mr. Corbett, whose part-time services were obtained by arrangement with the Department of Agriculture. Mention must also be made of information provided by Mr. H. M. Pendlebury, Curator of Museums, Selangor, with reference to certain entomological work which has been dealt with over the last few years.

It is with the greatest pleasure I place on record my appreciation of the help afforded by the Imperial Mycological Institute, Kew, not only from its Director, Dr. E. J. Butler, F.R.S., but also from every member of the staff. It is doubtful if one of the largest obstacles encountered during the writing of the book would have been successfully surmounted but for their ever-ready assistance, tendered over a fairly long period during which I was working there. The Imperial Mycological Institute should receive extended support from all quarters, for there cannot be the slightest doubt that the organisation

has made and occupies a unique place in its own particular sphere, and full financial support is merited. Mention must be made of the personal assistance given by Mr. S. F. Ashby, in connection with the organism commonly associated with the bark disease known as patch canker, and also for reading through the important section on panel diseases. I am grateful also to Dr. S. P. Wiltshire for the illustrations, Figs. 31 and 58, and to Mr. E. W. Mason for information supplied during certain discussions on fungi associated with rubber disease problems. I must mention my indebtedness to Miss E. M. Wakefield, of the Kew Herbarium, for help in finding the authorities for many of the scientific names of the plants mentioned in the book.

The illustrations should prove of the utmost value to any planter interested in rubber diseases. For the microphotographs, and a large number of the ordinary photographs, I am indebted entirely to Mr. H. Gunnery. It has been my personal feeling for many years that a great progressive step would be made if it could be impressed upon agricultural research workers that it would be of the greatest value if a closer touch could be maintained with the finer phases of microscopical work. Tropical research workers are more especially in mind. Mr. Gunnery was attached to my division for a period of twelve months, and I can confidently state that, owing to his activities, the research work of the division went forward very satisfactorily. All the intimate details, relating to the fungi associated with the various diseases of rubber trees, which could be dealt with during a short period were disclosed and new facts were obtained in every single instance. The features depicted in the illustrations of *Sphaerostilbe repens* are sufficient proof of this statement.

In connection with paintings and photographic illustrations, mention must be made of the effective work contributed by Mr. Lim Keng Chuan, artist at the Rubber Research Institute.

Grateful acknowledgment is made also of help from numerous planters in Malaya who have supplied information in the past, and in many cases given considerable help in field experiments. It would be invidious to single out individuals for special mention, for helpers have been so numerous that it is only fair that thanks should be tendered to the general planting community.

References to literature are given in chronological order, following the example set by the *Annals of Applied Biology*. No claim is put forward that an exhaustive list has been compiled, but an endeavour has been made to indicate the papers of major importance and also to direct attention to those of very early workers, which often escape notice since they are published in journals which have either changed

their identity or ceased publication. These short notes often contain sapient remarks which, if viewed hypercritically, might be regarded as mere hazards in the absence of supporting work, but in spite of this they are worthy of recognition.

A list of fungi recorded as occurring on rubber trees mainly in Malaya is included.

It was originally intended to divide the book into four parts, but the advent of restriction necessitated a change. The subjects intended for inclusion in the proposed Part IV were (*a*) Forestry methods as applied to cultivation in rubber plantations, and (*b*) Future possibilities in respect of planting high-yielding strains of rubber trees derived through bud-grafting or seed selection. Now that restriction of rubber is an accomplished fact, it is doubtful if it would be advisable to discuss pros and cons of the latter subject. After completion of Part III, therefore, the only subject remaining to be dealt with was forestry methods, around which much controversy had raged since 1930. In this book the subject has been dealt with at some length, but the main endeavour has been to show that there never was any real reason why the controversial issues should have been raised if the advocates of forestry methods had not made very wide claims for which little or no supporting evidence could be advanced. *Controlled* natural covers, comprising a mixture of shade-loving plants, which are the only type of plant capable of normal development under mature rubber, are but slightly different, and serve the same purpose as the controlled, leguminous cover crops which are established everywhere as the common practice in young rubber plantations. It is most satisfactory to know that the rank and file of rubber planters now generally speak of *controlled* forestry methods, the word "controlled", as contrasted to unrestricted or uncontrolled, being an addition which I myself insisted upon. The latest authoritative publication is entitled *The Uses and Control of Natural Undergrowths*, and the phrase "control of natural undergrowths" at once removes any objections which might have been raised in the past from a pathological point of view.

Parts I, II and III may be read quite independently of one another. Part III, dealing with the subject of pests and diseases of the rubber tree, should prove of most interest to planters. In many cases minute details relating to the structure of fructifications and production of spores have not been set out, for they are of little interest to planters, and investigators can obtain them from the publications cited. I hope that Parts I and II will receive due attention, for while the subject matter dealt with will present some intricacies to the lay-

man, every care has been taken to give the simplest and barest outlines compatible with utility. The planter who makes a study of these elementary treatises will be in a position to appreciate the remaining portions in a practical manner. Parts I and II may well serve as the basis for the examinations conducted by the Incorporated Society of Planters. A correct even if elementary knowledge of the anatomy and physiology of both the parasite and host plant is necessary if a true understanding of the disease problems which are met with in rubber plantations in Malaya is to be obtained.

A. S.

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INTRODUCTION

AT the beginning of 1913, when I took up official duties as assistant mycologist in the Department of Agriculture, Federated Malay States, there were few phytopathological records available, and there were many outstanding problems which required immediate attention. To-day the agricultural position in the rubber industry, in respect of pathological problems, is vastly improved.

A short historical résumé of the rubber industry as regards disease research in Malaya may prove of interest. At the outset, the one item worthy of note was the numerous changes which took place in the pathological workers appointed to the Department of Agriculture, in the first six years after the post of Government mycologist was instituted, in 1906. Carruthers, followed by Gallagher, and then Bancroft with Bateson as assistant mycologist, held office between 1906 and 1914. Early in 1914, F. T. Brooks arrived from Cambridge to take up a temporary agreement which terminated at the end of the year. The appointment of this experienced pathologist marked a new era, and it seemed unfortunate that circumstances prevented the appointment being made permanent at the time. Malayan agriculture would have gained considerably if such a step had been taken. I had the difficult task of following the example set by him, being ultimately appointed Government mycologist in 1916.

The research work carried out in the Department of Agriculture on diseases of rubber trees, up till 1926, is well known; in this year the proposed Rubber Research Institute of Malaya took concrete form and all the work on rubber tree diseases was transferred to the newly formed Institute. No detailed reference to the troublous times which the Institute passed through in the early years need be mentioned; but in 1930 the suggestion was made that I should be seconded from Government service to take over the post of Head of the Pathological Division, which had been vacated by Dr. J. H. Weir. After long consideration, the offer was finally accepted, and duties were commenced in 1931. The disease records available at the time were not extensive, but the present disease position is undoubtedly satisfactory, a fact which is freely admitted by eminent outside authorities. It may be of interest to readers in Malaya to know that Dr. E. J. Butler, Director, Imperial Mycological Institute, stated in his presidential address to the British Mycological Society, 1926, that "no one

can doubt, who knows the facts, that the rubber industry of Malaya has been saved not once but several times by the control measures devised by local mycologists against disease"; if this statement was applicable in years gone by, the records published in this work will provide convincing testimony that extraordinary progress has been made towards putting the industry in Malaya on the soundest possible basis, in so far that a safe guarantee can be given that large losses need not be anticipated from the plant diseases, now well known, if adequate safeguards are provided for their control. The dangers from outbreaks of new diseases must always be faced, but this contingency can be considered with equanimity if agricultural methods and procedure remain fairly stable. But changes in the rubber industry seem inevitable, and the introduction of bud-grafted material into planting practice may result, before many years are past, in very different disease problems arising for intensive investigation.

The foregoing is given prominence at this early stage to emphasise my firm opinion that there appears to be every justification for the claim that all expenditure on pathological work in Malaya has been repaid many times over. Unfortunately, the item cannot be shown as a concrete profit in the balance-sheet, and therefore there is difficulty in putting it forward as an item sufficiently impressive to attract immediate attention. The soulless science of economics naturally rules applied scientific work, and it appears that the only essential distinction between applied and pure research is that, in the former, profits must be clearly visible, while, in the latter, the completion of a line of research work is the primary consideration, and whether or not profitable issues may be the ultimate outcome does not affect the question. There is no doubt that the cynic was near the truth when he said, "Show me that a course is economical and expedient and I'll soon find you moral sanction for it", especially in the view of the unfortunate scientific officers who have fully proved their worth and who have had their posts abolished during recent depressed financial periods. Pathological research workers are often considered fortunate in possessing an argument which appeals when agricultural industries are undergoing profitable development. All men are keen to recognise the security offered by a satisfactory form of insurance, and active work on disease prevention is always encouraged during prosperous periods; no difficulty is encountered even if high premiums have to be paid. But the position is reversed, often exceedingly rapidly, during depressed periods, and premiums are often allowed to lapse. Even the most capable scientific research

workers may suffer, but this is one of the disabilities under which the worker engaged on applied research must labour.

The quotation mentioned above appears in a book describing the work done by the scientific staff of the Anglo-Persian Oil Company. Moral sanction is possibly not required, or becomes of the smallest significance in business undertakings, when the question of profit and loss is to be decided. But it is certainly good ethics to instil and practice sound economics in plant pathological work, and all recommendations for the control of plant diseases should be subjected to the acid test supplied by the query, "Will it prove a paying proposition?" I believe that all plant pathologists who intend undertaking applied research in large agricultural combines should have a knowledge of business and financial details included in their training curriculum. Scientific workers, when engaged by business combines, are expected favourably to influence the future developments of the business by their work, and as a direct result, to maintain or increase the profits. It is suggested that a better understanding between the business directors and the scientific workers would be more rapidly established if the latter had passed through a course of training in business methods and organisation; the inclusion of such a course in a scientific officer's training might lead to their work being suitably appreciated from the commencement, and eventually it might be possible to include the scientist as an integral part in the business organisation.

There is no special aim to be attached to this book, beyond recording the progress of pathological research in Malaya. It is hoped that the book will make a direct appeal to practical planters. The effort will be aided considerably by the programme inaugurated by the Incorporated Society of Planters, whose leaders realise keenly that a change is impending in the rubber industry which is likely to be fraught with far-reaching consequences. In the early days, a plantation could be successfully established only by the acquisition and maintenance of a settled labour force, and the planter who had a flair for controlling labour became the successful plantation manager. This still remains an important part of a planter's duties, but additional attainments are now required, and these will become still more valuable in the not far distant future. Many changes have come about recently, and the successful planter of the future must possess a much closer knowledge of modern developments in planting and must, moreover, be able to control and put the concepts into practice. The Society has established, for its members, a series of courses along varied lines appertaining to rubber planting, and examinations are

held at intervals. This is a very definite forward move, and it is encouraging to think that the present volume on diseases and pests of the rubber tree will be more readily appreciated than might otherwise have been the case.

A broad treatment has been adopted as far as possible, which makes for a discursive account and leads to more repetition than might be considered necessary. Possibly, these obvious repetitions will not find favour with those readers possessing an intimate knowledge of plant diseases. But in view of present-day working conditions, when the planter's daily routine duties are much more arduous than before the depression, they will seldom feel the urge towards long spells of studious reading. Intermittent periods of "dipping-in" will be the rule, and, under the circumstances, it seems not an undesirable feature to repeat the items of special interest to planters wherever the opportunity arises. The above is purely a personal view and I hope that planters will benefit from the method adopted. The portion dealing in a very elementary way with the subject of forms and functions of plants represents an endeavour to provide the practical planter with the essential fundamentals of the important vital activities of the host plant, and to emphasise the point that in plant life there is a complete circulatory system, a fact which is not understood amongst planters in general.

The needs of active investigators of rubber disease problems have been kept in mind, and provision for them has been made by indicating the directions for future research on particular problems. In addition, an attempt has been made to compile and include as much as possible of all the reliable information which is available.

A subject of considerable importance, requiring close consideration by phytopathological workers, is the confusion arising from the numerous misidentifications of the fungi responsible for even the commonest plant diseases. Little can be gained by constant disagreement over the correct systematic position and name of an organism causing a common plant disease, and it certainly leads to lack of confidence between planters and the pathological workers who are called upon for advice. The story of the name-changing in respect of the fungus causing white-root disease is given on page 76, and it does not reflect much credit upon the workers who have created the position as it now stands. There is still conjecture regarding the name *Fomes lignosus*, as is shown by an article published in 1933, in which the author apparently accepts the name of *Rigidoporus microporus*, proposed by Van Overeem. To avoid confusing the planter, the procedure followed in this book is, when there is the slightest doubt

surrounding a newly proposed name, to utilise the old name which has been in common use. In fact, up to the recent publication of Corner's work on the fungi associated with the brown-root disease of tropical crops, there was much reason to doubt whether it was worth while, in connection with disease problems, taking the systematic side of the work really seriously. The critical and close analytical work of Corner represents an effort which will set a satisfactory standard for the future, and there is no doubt that the information given in his article is of the greatest importance towards a correct understanding of the widespread problem presented by brown-root disease.

An attempt has been made to show that an ideal condition is created, in the tropics at least, for research workers on plant diseases, when critical systematic work of the type of Corner's is combined with full researches into the structure of parasite and host plant and the interactions between them. In respect of the latter, climatic and soil factors exert a very large, if not entirely dominating influence. The routine outlined would form a basis for a detailed but extremely large and varied programme, and it is only very occasionally that opportunities arise for dealing completely with all the items, or even with all the major ones requiring immediate attention. Research work on disease problems in the tropics, and perhaps in other parts of the world, is governed entirely by the opportunities which present themselves during any particular period. The root disease caused by *Fomes lignosus* was always prominent from the earliest days, and an intensive research would undoubtedly have provided interesting information if time and attention could have been found to devote to the subject. But while this was fully recognised, the problem did not prove to be an outstanding one in the period around 1910–15, and various new problems came up for immediate elucidation. For example, the cause of discolorations in white crepe and sheet rubber, followed by the necessary careful enquiries into the rapid spread of pink disease in various parts of the country, had to be dealt with quickly. The root disease caused by *Ustulina zonata* was then recorded during the time Brooks held office as Government mycologist and was investigated by him. A little later, the root disease caused by *Ganoderma pseudoferreum* was first recognised by Belgrave as an affection distinct from the one caused by *U. zonata*. About the same time, *circa* 1916, the panel diseases known as black stripe and mouldy rot first made their definite appearance in Malaya, and the problems presented by these diseases required sustained work; following on these there was a sudden and widespread outbreak of brown bast,

which affection created a considerable scare. All these developments occurred during the period 1913–18. From 1917 to 1920 I was away from Malaya engaged on war service.

After 1920, a second period was entered upon, and the investigations on brown bast occupied practically the whole time over a four-year period, though it was possible to undertake preliminary observations on root disease problems, and the results obtained were of such interest that it was obvious this problem still required further, careful investigation. With the inauguration of the Rubber Research Institute of Malaya, research work on rubber diseases passed into other hands; but the root disease problems in rubber plantations still remained for solution when I joined the Pathological Division in 1931. The opportunity for dealing directly with the root disease problem had obviously arrived and no time was lost in drawing up a suggestive, provisional, research programme, which was placed in the capable hands of Mr. R. P. N. Napper, who had recently joined the staff of the Institute as a junior pathologist. Thus it had taken nearly twenty years for an opportunity to materialise of undertaking research on root disease problems in Malaya. Similar experiences could be related as being encountered in other tropical countries, but this is cited as indicating that, in tropical work, the choice of a line of research is entirely dependent on opportunity; if good opportunities present themselves and full advantage is taken of them, most researches can be expected to produce profitable results.

An important point now arises for consideration. There will be little opposition to the view that in order to obtain a completely satisfactory picture of any plant disease problem neither the investigations on the fungus, nor on the host plant, nor on the external factors influencing them, can be neglected. The side which shows up most prominently at the commencement would naturally receive the earliest consideration. It is obvious that, in the problem of brown-root disease, the identification of the causal fungus was of primary importance, and now this is settled there should be few further complications. In a so-called physiological disease, such as is presented by brown bast, the host plant requires the greater consideration, but in both cases outside factors are of such a degree of importance that they must also receive attention. These two cases might be said to be exceptional. The influence of external factors appears pre-eminent in all disease problems which have been encountered in Malayan rubber plantations, and, once satisfactory evidence has been obtained as to the causative agent of the disease, should therefore claim priority of attention. If we instance *Oidium* leaf-fall as an

example, it is obvious, from a practical point of view, that in the early stages of the investigation a long period should not be spent enquiring into the intimate details attached to the difficulties of isolating the fungus in the laboratory and cultivating it artificially. After the initial investigations have been made, it is obvious that atmospheric factors are of the greatest significance since they profoundly influence outbreaks of this disease. It is not then difficult to appreciate that, as only limited opportunities generally exist for exhaustive research, the investigations into atmospheric factors should claim early consideration, if control methods are to be arrived at expeditiously. This point has been kept well in mind in the work carried out on *Oidium* leaf-fall by Mr. F. Beeley; laboratory details on the isolation of the fungus, growth in culture, artificial inoculations, etc., will undoubtedly follow later when the full control routine has been satisfactorily established. A similar routine has been followed by Napper in his root disease researches; it is the picture as presented in the field which is of paramount importance, and once a satisfactory scheme of control is established, other more intimate details respecting the causal fungus and host plant can be dealt with.

A specific statement is made above that one aspect of a disease investigation should not be neglected at the expense of another. In the past, it seems that full importance has not been attached to the question of external factors and influences; in fact it can be truthfully said that the study of this side has often been sadly neglected. This statement is naturally more applicable in cultivations of permanent and semi-permanent trees than in annual cultivations, as will be fully appreciated when rubber tree diseases are dealt with in detail.

It is suggested that, once the causal fungus has been identified satisfactorily, the detailed study of host parasite relationships can be considered of secondary importance, as compared with the intensive investigation of external factors likely to be concerned in initiating and influencing the spread of the disease. This brings up the debatable question of the compilation of lists of fungi associated with the host plant and whether these should be considered a matter of primary importance, since, in the tropics at least, phytopathological workers are only too few in number to cope with the numerous problems awaiting investigation. Lists of fungi undoubtedly serve a useful purpose, but it can hardly be doubted that exaggerated importance has been attached to this line, in so far as it has probably led to the neglect of the all-important investigations on the effects of climatic, soil or other outside factors on disease problems. The latter branch of study seems of such great importance to the writer

that a further suggestion might be made, viz. that all pathological workers should receive, during their course of training, a grounding in the use of meteorological instruments. These could then be adequately utilised in researches on plant diseases affecting permanent or semi-permanent cultivations. Information along these lines should be sought for from the inception of the research, more especially on the subject of diseases of aerial portions of plants. This suggestion is much more to the point at the present date than it would have been several years ago, for the improvements in self-recording instruments render the routine simple, and with movable sets, which can easily be transferred from one district to another, much of the unreliable information commonly obtained hitherto would be avoided. The above remarks are offered in the hope that the influence of the various factors operating outside host and parasite will receive full recognition in future researches on plant diseases.

PART I

GENERAL REMARKS ON PLANT DISEASES, STRUCTURE, REPRODUCTION, AND PHYSIOLOGY OF FUNGI

CHAPTER I

GENERAL

Losses from Plant Diseases, etc.—Mycologist *versus* Plant Pathologist—Modern View of Plant Pathology with reference to Rubber Tree Diseases in Malaya—New Work carried through, 1931–34.

THE study of fungoid and bacterial diseases in their true relation to extensive cultivations is of comparatively recent date, and it is only during the last few decades that the losses suffered by cultivators have been realised and approximately estimated. Generally, it is freely admitted that cultivators suffer heavy financial loss owing to the ravages of plant diseases, but in spite of the extraordinary advances made by scientific workers in protecting cultivators from plague and pestilence, there is still no absolute security against loss. This is clearly evident from the daily reports of enormous damage to grain crops owing to abnormal drought conditions during 1934. The ruin of the coffee plantation industry in Ceylon many years ago, as a result of the outbreak of the coffee-leaf disease, caused by the fungus *Hemileia vastatrix*, is well remembered by tropical cultivators in the East. In connection with the cultivation of rubber plantations, the activities of the fungus causing the South American leaf disease have frustrated all the efforts to establish its successful cultivation in British Guiana and Surinam, and there seems little hope of the rubber industry ever becoming permanently established in these countries. In Malaya at the present time, most estates possessing large areas of old rubber between fifteen and thirty years of age fully appreciate that an enormous number of trees may figure in the casualty lists, the chief agent of destruction being the fungus *Ganoderma pseudoferreum*, a parasite which affects the root systems and spreads by root-contact. There seems little reason to doubt the statement that this disease will prove the "limiting factor" which will prevent the economic development of old rubber areas in Malaya.

This is all the more regrettable as the losses accruing from this cause are largely preventable. There is not the slightest doubt that old areas of rubber trees of the age indicated, which have escaped serious disease attacks, will retain satisfactory yielding capacities and continue to be classed as economic units, even if in the future high-yielding, bud-grafted areas are developed on a large scale. This statement is perhaps of greater significance now that restriction of rubber exports is an accomplished fact, for one result of this policy will certainly be to retard any scheme designed to increase the yielding powers of rubber areas.

It has been pointed out above that it is only relatively recently that the study of plant diseases has been intensively taken up. This movement was probably stimulated by the recognition, tardy though it was, of the extensive losses caused to cultivators by plant diseases. Since those caused by fungi were most conveniently and, perhaps, the most easily studied, the expert on fungi, i.e. the *mycologist*, was the first class of investigator to be closely engaged in the study of plant diseases and of measures for their control. But it became increasingly evident that the pure mycologist could not be fully equipped to carry forward all enquiries into phytopathological problems. The position might have been much worse but for the fact that a student of fungi must have a good groundwork of training in general botany. All professional mycologists had, from their training, the capacity to obtain a knowledge of the general morphology of the higher plants and so could appreciate the possible reactions of the host plant towards fungal invasion, though their knowledge along these lines would, of necessity, be somewhat limited. The next development in phytopathological research was the full recognition of the importance of the reactions of the host plant, and this line of investigation then became the particular study of the pathologist.

Many writers have dealt at length with the presumed antagonistic positions of the mycologist and the plant pathologist. They have considered that the older conception of mycology has overpowered to some extent the newer science of plant pathology and that the claims of the latter have been dwarfed and obscured, on account of the unfortunate English usage of the terms mycology and mycologist. The great plant phylum of *Fungi* happens to form a common basis for the two studies. There are tens of thousands of fungi for the mycologist to study, but a comparatively small number only are active agents in causing plant diseases. In addition to fungi there are numbers of other agents causing plant diseases, and to these the plant

pathologist must give full consideration, i.e. virus diseases; physiological diseases such as brown bast; bacterial diseases; phanerogamic plants causing maladies of different plant species. The mycologist engaged solely in the study of fungi would seldom venture into the realms indicated. While the fungi form a common basis for study, the approaches thereto are usually very different and set far apart. It seems to the writer that there should be no real antagonism between mycology and pathology with its wider scope, for close contacts with nearly related sciences should necessarily be maintained if a complete understanding of a subject is to be arrived at. The pathologist studies the nature of disease, whether of fungous origin or otherwise; the prevention and cure of disease; the economic losses caused by disease of whatever origin. Mycology, on the other hand, studies the structure and development of fungi with a view to understanding their activities as a component part of the great plant world. Further, as the main plank in the platform of the plant pathologist (viz. reaction of host and parasite with special reference to external environmental conditions) is of little or no concern to the mycologist, there should, once the true position becomes clear, be no indication of the "fissiparous tendency" stage. There can be but little doubt that plant pathology has now won full autonomy as an independent science, but if the best results are desired, it should not be divorced from associated studies.

The influence of external factors, such as those of atmosphere and soil, are emphasised in the paragraphs immediately following, and in all references to the control of the important diseases, special attention has been directed to the economic side. In these wide fields the mycologist *qua* mycologist is an utter stranger, and why the old conception of mycology should ever have come to dominate plant pathology is indeed surprising. It cannot be said that this domination is so apparent at the present day as it was in the past, and when the great influence of climatic and soil differences and changes on plant diseases becomes more generally appreciated, there will be no more wordy warfare on this subject.

By keeping the modern viewpoint of plant pathology in due prominence, the writer hopes to make it abundantly clear that a successful attempt has been made to elucidate many of the more important plant-disease problems in the rubber plantations of Malaya. In taking a wider and more general concept of root diseases, it has been found possible to define a new policy which will have far-reaching effects in future plantings of rubber. With respect to the various species of *Fomes* causing root diseases, the idea that *F. lignosus*,

Ganoderma pseudoferreum and *F. noxius* were each the cause of a particular disease which had no intimate relationships with one another, has been discarded, and a new idea is promulgated to the effect that these important root diseases would be found to have a strong family relationship physiologically, and that the many practical problems to which they give rise in the field are but merely variants of a single general problem. Preliminary studies on red-root and brown-root diseases, in 1925, indicated the probable importance of the physiological concept, but the opportunity for full proof did not arise until the last three years, and Napper has now proved the matter up to the hilt.

Pioneer rubber planting commenced in the middle eastern countries around 1906, and the flood-tide actually started about the boom period of 1910. There is a tremendous acreage of rubber over twenty years of age in existence; much of this approaches thirty years of age, and a small proportion is even over this figure. It is only just beginning to be adequately realised that a large proportion of the old rubber areas in Malaya, carrying trees over twenty years of age, are seriously affected by a root disease which is causing a tremendous amount of damage. Attention was directed to the potential dangers facing Malayan rubber plantations in 1925, when the root systems of some 1400 trees, fourteen years old (which did not appear more seriously affected by root disease than other trees of similar age), were opened up in an experimental area. The results were most unexpected. The percentage number of diseased trees totalled 56. The diseased trees could be divided into two classes:

(I) Trees affected with a parasitic fungus in the lateral roots, i.e. the fungus had not progressed sufficiently up the side roots to infect the main stem.

(II) Trees showing the fungus making active progress in the main stem, having gained access to this region through diseased lateral roots.

The total number of diseased trees was approximately equally divided between the two classes. All the trees in class (I), i.e. those slightly affected in the lateral root system, could have been saved by the simple excision of the diseased roots, followed by complete extraction of the diseased portions from the soil. The diseased trees falling in class (II) had to be completely removed.

The actual demonstration of the position outlined above showed quite clearly that if such proved to be of general occurrence throughout Malaya, there was good reason for issuing a warning that grave

dangers existed of large tree-losses in the future, more especially if the facts were ignored and control measures were neglected. It appeared that little notice was taken of the warning. The industry was flourishing at the time, and most responsible planters showed the not unusual attitude of considering the report interesting, but on the alarmist side. The intrepid manager, who was really responsible for exposing the true facts of the case against the writer's original opinion, deserves high commendation for his prescience in respect of the true position. As a result of the neglect of this warning, Malayan plantations are now faced with a situation such that large areas of old rubber, which should be capable of yielding exceedingly well at the present date, will have to be replanted if they are to be brought back into the lists as economic units.

The statement that old trees which have remained unaffected by root disease should give very satisfactory yields can be supported, for there are old rubber areas, carrying trees twenty-five years of age, which still show excellent yielding capacity. These old areas, which are in good order to-day, have been specially guarded against root diseases, and their percentage infection at the present date can be considered negligible. But the great majority of estates with rubber trees over twenty years of age cannot report this happy state of affairs. It was becoming increasingly evident, from the number of estates actively engaged in replanting portions of their old areas when the writer left Malaya, in February 1934, that the position is being frankly faced, and that appropriate steps are being taken to rectify the position.

Taking these facts into consideration, it is necessary to emphasise once again the need for continuous, comprehensive research on plant diseases, particularly in a country such as Malaya, where true prosperity lies in agriculture. In normal times the need is admitted, but ready approval to provide for research is not met with during depressed financial periods, more especially in those agricultural industries in which speculation is a prominent feature. During slump periods the scientific needs of agricultural industries are usually sadly neglected, and one of the first efforts to reduce expenditure is the modification or even complete neglect of the measures to prevent losses from preventable diseases. Even during normal periods, the speculator and producer, who often join forces and claim to "pay the piper", realise but little that the tree of science does not readily yield its fruits and that long and arduous toil is usually necessary before a good crop can be secured. Scientific investigators can seldom respond to the "quick result" tune which is so often called for, or at least the

results which do accrue quickly cannot, to any great extent, be relied upon.

Continuous work over a prolonged period had prepared the way for a general plan of campaign in respect of rubber disease investigations in Malaya, and the period from 1931 to 1934 proved a specially fruitful time. As the years have passed it has become recognised more and more that fungus diseases of rubber trees need observing from a new angle. Firstly, certain diseases have been shown to possess similar fundamentals, and when the question of control is being considered, diseases formerly classed as separate units must be grouped together so as to ensure full and economic control. Secondly, it is becoming more and more obvious that outside factors have the greatest significance in connection with rubber tree diseases. For instance, panel, stem and leaf diseases are largely influenced by meteorological factors; the root diseases which appear in a rubber plantation entirely depend on the vegetation previously existing on the area, while direct atmospheric effects from lightning damage, scorching by the sun's heat, etc., play an important part in causing damage in certain areas.

Many references have been made already to the names of the fungi causing the more important diseases. It is now intended to direct attention to the more important matters which have come under special notice since 1931, and this provides a convenient opportunity to present in tabular form the various diseases dealt with, together with their common names, if any, and the names of the causal fungi. This will aid in preventing misunderstanding regarding the causes and common names of rubber tree diseases.

ROOT DISEASES

Common Name	*Names of Causal Fungi*
White-Root Disease . .	*Fomes lignosus*, Klotzsch
Red-Root Disease . .	*Ganoderma pseudoferreum* (Wakef.), Van O. et St.
Brown-Root Disease. .	*Fomes noxius*, Corner
Dry-Root Rot . .	*Ustulina zonata* (Lev.), Sacc.
Sometimes called Stinking Disease	*Sphaerostilbe repens*, B. & Br.

Tapping Panel Diseases

Common Name	Names of Causal Fungi
Mouldy Rot . . .	*Ceratostomella fimbriata* (E. & H.), Elliot
Black Stripe (commonest cause in Malaya)	*Phytophthora palmivora*, Butl.
Patch Canker (commonest cause in Malaya)	*Pythium complectens*, Braun
——	*Marasmius* sp., probably *M. palmivorus*, Sharples
Brown Bast . . .	Physiological disease

Stem Diseases

Common Name	Names of Causal Fungi
Pink Disease . . .	*Corticium salmonicolor*, B. & Br.
Stem Ustulina . .	*Ustulina zonata* (Lev.), Sacc.
Diplodia Die-back . .	*Diplodia* sp.
Thread Blight . . .	*Cyphella heveae*, Mass. ?
Horse Hair Blight . .	*Marasmius equicrinis*, Mull.
Mistletoes . . .	*Loranthus* species

Leaf Diseases

Common Name	Names of Causal Fungi
South American Leaf Disease	*Melanopsammopsis ulei* (Henn), Stahel
Phytophthora Leaf-fall .	*Phytophthora meadii*, McRae
Oidium Leaf-fall . .	*Oidium heveae*, Stein.
Mite Attack associated with .	*Gloeosporium alborubrum*, Petch, and *Gloeosporium heveae*, Petch
Bird's-eye Spot . .	*Helminthosporium heveae*, Petch
Shot-hole Leaf Disease .	Several fungi are found associated with these symptoms
Rim Blight . . .	*Ascochyta heveae*, Petch *Sphaerella heveae*, Petch *Guignardia heveae*, Syd.
Red Rust (more common on Tea)	*Cephaleuros mycoidea*, Karst.
Sooty Moulds . . .	*Capnodiae* spp.

Taking the diseases in the order presented in the book, it will be seen that matters of importance have been under consideration since 1931, and in most cases valuable additions to our knowledge have been made. On the subject of root diseases caused by the *Fomes* type of fungi, our views have been completely reversed. The following short statements indicate very briefly the important features which have recently been dealt with in connection with the various diseases which affect rubber trees in Malaya.

Root Diseases

Ustulina zonata.—Nothing of importance to report.

Sphaerostilbe repens.—Noteworthy additions to the morphological structure of the fungus have been made (Figs. 10, 11 and 12). The fact that outbreaks of the disease are closely associated with the flooding of rubber areas is emphasised, and further cases are described.

Fomes lignosus.—Factors which were formerly considered to influence the spread of this disease were:

1. The independent travel of the mycelium through the soil.
2. Spore infection of old jungle stumps, and as a result these became primary centres of infection.
3. Trenching was recommended for control.

The above are now considered of little importance in Malaya. It has been established that rubber trees are found diseased only under the following conditions:

1. When their roots come into direct contact with diseased jungle wood. This is supported by De Jong's recent work in Java.
2. When infection has been brought about as a result of the natural increase in length of roots, so that they pass into soil areas containing diseased jungle timber. It is not brought about by the growth of the mycelium through the soil.

If the above is correct, it is clear that the dangerous soil areas are *disclosed* by the increase in length of the roots. As a consequence trenching will be of little use in preventing spread. The essential item in control is the complete removal of infective material in the shape of infected timber and stumps derived from jungle trees.

Ganoderma pseudoferreum.—This disease was previously considered to be one primarily associated with rubber trees ten years of age or over, and therefore entirely distinct from the disease caused by *Fomes lignosus.* But it has been proved beyond doubt that the two

fungi start in exactly the same way. They attack trees in the jungle, and when this is felled, the soil areas carrying the diseased trees form the danger zones for the young rubber plants. The danger zones formed by the presence of *G. pseudoferreum* are not so conspicuous in the early years as those of *F. lignosus*. The latter fungus shows more vigorous growth and the losses due to it reach a peak about the fourth or fifth year, whereas *G. pseudoferreum* seldom becomes prominent before the tenth year. As both fungi spread from one tree to others by root-contact, control measures for one apply equally for the other, and disease zones, centres or knots of both fungi, consisting of buried jungle timber, must be removed as early as possible if successful control of these root diseases is to be established in new plantings. A combined system of control for both diseases removes all the doubts which have often been expressed in the past as to the economic outcome of measures advised for controlling the disease caused by *F. lignosus* alone.

Fomes noxius.—Corner's work on the identification of the fungus causing brown-root disease of rubber trees and other tropical crops has already been mentioned. The facultative parasite responsible for the disease has been named by him *Fomes noxius*, and he shows that it has been confused with *Fomes lamaensis*, which, although closely related, is a harmless saprophyte.

Panel Diseases

Nothing new can be reported in respect of black-stripe or brown-bast diseases, though the description of the latter here provided is the first complete account to appear in book form in a British publication. The latter remark applies also to mouldy rot, a disease which has not hitherto been reported from any other rubber-growing countries except Java and Sumatra. The peculiar manner of its spread from one district to others, often separated by a distance totalling hundreds of miles, can only be explained by the spores being carried upon clothes or implements (such as tapping knives) during the migration of human beings. It has further been fully established that, when water vapour is present in too abundant quantities, mouldy rot is practically impossible to control by known methods. This finding is of the greatest importance when any proposal is made to establish, under mature rubber trees, a natural cover comprising a mixture of shade-loving plants. The natural result of this would be the accumulation of large amounts of water vapour, due to the transpiration of the cover plants, more especially if adequate ventilation is not provided.

New observations have also been made in Malaya on patch canker, and the most common agent in the country has been ascertained to be the fungus *Pythium complectens*, Braun. There has been some doubt about the actual causal fungus and authorities have previously considered that a species or strain of *Phytophthora* was the cause in other countries. The common association of patch canker, following on lightning damage, has moreover been fully established.

A new record has been made of a minor panel disease and its origin, for the fructifications of the causal fungus have now been successfully developed. The fungus proved to be a species of *Marasmius*, probably *M. palmivorus*, Sharples, which is commonly found on disintegrating coconut material.

Stem, Branch and Leaf Diseases

The only item of note under this heading is the work on *Oidium heveae*. The conditions favouring the development of the disease have been fully described and methods of control by means of sulphur dusting have been devised.

Insect Pests

Noteworthy items under this heading are those concerning the work on white ants and the white grub plague; the latter is the grub stage of *Psilopholis grandis*. The new record of *Thosea sinensis* on rubber is also worthy of note.

Direct Agencies affecting Rubber Trees

The investigation on lightning damage in rubber plantations in 1933 is specially noteworthy. The records obtained show that this agency must be considered to be a major cause of damage, a fact which has not been recognised before. The writer has produced conclusive proof that lightning is a primary agent in the initiation of coconut-palm affections in Malaya, and it is not at all improbable that evidence will be obtained in years to come that lightning plays an extensive part also in the tree affections seen above-ground in rubber plantations.

CHAPTER II

CAUSATION OF DISEASE, ETC.

Causation of Plant Diseases—Vegetative Structure of Fungi—Reproductive Structures and Classification of Fungi.

CAUSATION OF PLANT DISEASE

WHEN considering affections of the rubber tree, the only distinction existing in the minds of planters is that lying between fungus diseases and insect pests. Such a distinction does not meet the situation when the real facts are given due prominence, i.e. that derangement of function, brought about by any cause, organic or inorganic, may result in a diseased or pathological condition. Leaving insect pests out of consideration for the time being, and confining remarks to the common diseases of rubber trees, various causes, other than fungi, can be distinguished, as under:

(*a*) Affections caused by phanerogamic parasites, such as mistletoes (*Loranthus* spp.), on rubber trees.

(*b*) Affections caused directly by derangement of function, without an obvious organic cause, as in the case of brown bast of rubber trees; this affection is non-transferable by ordinary methods from diseased to healthy trees.

(*c*) Affections which occur owing to unsuitable agricultural conditions. In many common affections of rubber trees the latter form the main predisposing factors towards disease.

The groups of disease-causing agencies listed above indicate the wide range which exists outside the fungi, even in rubber plantations. Fungi, nevertheless, must be considered of primary importance in this crop. But there are, in addition to fungi, two important agencies causing diseases of cultivated plants, examples of which have not yet been reported from rubber estates. In world economy, the diseases caused by these agencies are of importance equal to, if not greater, than those caused by fungi, and are known as (1) Bacterial diseases and (2) Virus diseases. The latter class has attained great prominence in recent years, and work on the specific diseases comprised in the group is being most actively pursued at the present date.

At this point it will probably be of assistance if the schedule of operations worked to during a disease investigation is indicated; in

particular, when the causal organism is being sought for. Organisms, such as bacteria and fungi, which can be identified by specific form and other characteristics, and which may be constantly associated with specific symptoms of a particular plant disease, must first be isolated from diseased portions, with a view to growing them entirely alone, unmixed with other organisms, on artificial culture media of suitable composition. It is by this means that "*Pure Cultures*" are established. Attempts are next made to inoculate healthy plants with small portions of the organism grown in pure culture. If the disease can be successfully transmitted to healthy plants by means of artificial inoculations, and the typical symptoms reproduced, the attempt should be made to re-isolate the organism from the plants inoculated. If the organism can be re-isolated and again successfully established in pure culture, and is found to be identical with the one originally isolated from diseased tissues, it is considered that the normal disease cycle has been completed. This is, moreover, regarded as satisfactory evidence that a particular organism is the cause of a disease distinguished by certain characteristic symptoms. The cycle of events is designated as *Koch's* cycle, because it was first formulated by the famous pathological investigator Koch, and is regarded by all pathological authorities as a first necessity when attempts are being made to establish the cause of any particular plant disease.

No further remarks are necessary at this point on the diseases caused by the agencies mentioned under (*a*) and (*b*) above. Those caused by the agencies mentioned under (*c*) still require much attention. Their investigation is by no means simple, for it is always a difficult matter strictly to evaluate the exact, or even the approximate, influence which any particular set of abnormal conditions exert towards setting up a pathological state. Unfavourable climatic or soil conditions, etc., often lead to a considerable reduction in vigour, and the final result is a much greater predisposition to attack from disease-causing organisms. Nowell suggests the term *debility diseases* for affections of this type.

For comparative purposes, virus, bacterial and fungus diseases can be contrasted as regards their size as they appear under the microscope. Fungi are forms of plant life of relatively simple structure, but with a definite and distinctive one, often visible to the naked eye and easily visible under the microscope. The organisms comprised in the group of Bacteria are comparatively very minute in size, but they possess a definite structure which can be recognised under the higher powers of the microscope. The group contains forms which may be considered as transition forms between the animal and plant kingdom.

With regard to virus diseases, no organism with a definite structure has ever been demonstrated with certainty, and if particles of definite structure are associated with these diseases they must be exceedingly minute, and ultramicroscopic in size, i.e. not visible under the microscope. That virus diseases are transferable from diseased to healthy plants is proved by obtaining plant juice extracts from diseased plants and inoculating small quantities of the extract into healthy plants. The spread of virus diseases is commonly found to be dependent on an insect vector.

Nowell remarks that as no strict definition of diseasė can be given there is no fixed limit to a list of disease-causing agencies. But excepting brown bast and the damage done directly by atmospheric agencies, there is no necessity to go beyond the subject of damage caused by fungi and insect and animal pests, when reviewing the affections of rubber trees. The section devoted to insect and animal pests is merely an attempt to compile as much reliable information as possible from the scattered literature on the subject, and to give, in addition, the information obtained over the last few years in Malaya.

While the most important causes of plant diseases have been shortly referred to, no mention has been made of two other groups of organisms which cause plant diseases of some importance in other countries. These groups are known as (*a*) *Actinomycetes*, (*b*) *Myxomycetes*. The organisms included in the former show relationships to some of the filamentous bacteria and also to certain fungi, but they are probably most nearly related to the former. Diseases of potatoes, mangolds and beets have been recorded as caused by these organisms.

The myxomycetes are a group of organisms devoid of chlorophyll, having a preponderance of plant characters, but possessing some animal characters. The common finger-and-toe disease of turnips, and the corky scab of potatoes, are probably the best known diseases caused by organisms belonging to this group.

VEGETATIVE STRUCTURE OF FUNGI

Before commencing this section it will be advisable to state at once the fundamental distinction between fungi and all other groups of plants which are higher in the scale of organisation. All parts of fungi, both vegetative and reproductive, are devoid of chlorophyll, i.e the green colouring matter found in all the higher plants, and this results in a fundamental difference between the fungi and the higher plants in the matter of food synthesis.

The vegetative portion of a fungus is known as the *Mycelium* and is usually quite simple in structure. It is commonly made up of a mass of intertwining filaments, microscopic in size. Each individual filament is spoken of as a *Hypha*, so that the mycelium is composed of a number of hyphae. The mycelium is usually found permeating the invaded substance from which are absorbed the nutrient materials required. The hyphae, in most groups of fungi, are divided into short cells by the formation of cross-walls, but in certain groups no cross-walls or only very few are formed, so that a hypha simulates a long, undivided tube, e.g. *Pythium* and *Phytophthora*.

The technical terms used by Gaumann and Dodge in their recent text-book for the vegetative structures developed by fungi will be used here. In many cases the hyphae grow together in groups, intertwine, adhere and form a thick tissue which is termed *Plectenchyma*. If the single hyphal elements are still recognisable as such, the tissues formed are termed *prosoplectenchyma* or *prosenchyma*; if the hyphae have lost their individuality so that they lie beside each other (in sections), with the cells appearing isodiametric and continuous, as in the parenchyma of higher plants, the tissues so formed are termed *paraplectenchyma* or *pseudoplectenchyma*.

The hyphae may become concentrated and aggregated into thickish threads known as *rhizomorphs*, structures which may attain to a considerable degree of complexity. Rhizomorphs indicate a further step in the development of plectenchyma. They arise chiefly from parallel hyphae and often have a definite apical growth from an apical meristem, as in the root-tips of higher plants. Under suitable conditions, they may again spread out in sheets of mycelium. In the higher forms, a dark, thick, irregularly intertwined rind and a loose, white core are differentiated from parallel hyphae. They serve chiefly for transport of food in saprophytic fungi. Occasionally the conducting function becomes less evident and they attain a more *sclerotic* character. In parasitic fungi, the conducting function of rhizomorphs must be considered definitely of a secondary nature as compared with their ability to withstand adverse conditions.

In sclerotia the plectenchyma appears tuberiform, with a firmer pseudoparenchymatic rind and a looser prosenchymatic core. This structure serves to carry the organism over unfavourable conditions of growth and, with the return of normal conditions, it "germinates", developing into the usual mycelium or into a fructification.

Gaumann and Dodge use the term plectenchyma as indicated above, in connection with tissue developed by fungi which form tuberiform sclerotia. If such usage is valid, it seems equally so when

the term is applied descriptively to any aggregations of fungus tissue, whether in the typical form of rhizomorphs or as definite lines running through the woody tissues of diseased rubber trees, usually black or brown in colour. If this view is accepted, plectenchyma of different types is developed by all the fungi causing the major root diseases of rubber trees. The term *external* plectenchyma can be used conveniently for the *external* rhizomorphs of *Fomes lignosus* and *Ganoderma pseudoferreum*, and the term *internal* plectenchyma could be applied to the black lines of fungus tissue which are always prominent in the roots of rubber trees affected by *Ustulina zonata*. In the latter case, the internal plectenchymatic tissue has lost the typical rhizomorphic appearance, but in the case of *Sphaerostilbe repens* the internal plectenchymatic strands, of microscopical size, which grow through the diseased cortical tissues, retain the typical rhizomorphic appearance. In this connection it may be of interest to state that when *Sphaerostilbe repens* is grown in pure culture, the mycelium always forms small, rhizomorphic strands, which are clearly visible to the naked eye. Fig. 8 (*d*) will show that *Ustulina zonata* develops similar structures in pure culture.

Fig. 10 illustrates the microscopical rhizomorphs of *Sphaerostilbe repens* running through the diseased cortical tissues of the root of a rubber tree. It shows the apical meristem from which growth in length takes place and is reminiscent of Hartig's figure given in Gaumann and Dodge's book. Fig. 21 shows the internal plectenchyma formed by *G. pseudoferreum* in diseased rubber roots; this fungus also develops typical external rhizomorphs and rhizomorphic membranes.

This subject will be again referred to after the root diseases of the rubber tree have been described. Nothing has so far been said regarding the utility of rhizomorphs in the causation and spread of plant diseases, and but little has been published in the literature on this subject. An extract from Butler's book will therefore prove a useful introduction:

> Such specialised strands are known as "rhizomorphs" and they may reach a considerable degree of complexity of structure in some cases. All these mycelial strands are capable of growth at the tip, sometimes extending for yards and branching and anastomosing freely. Their use is readily understood. Single hyphae are delicate and easily injured, as by insects. The rhizomorphs are usually tough and hard to damage. By their vigorous growth they permit of extensive spread. They are also, owing to their structure, able to withstand drying or other adverse conditions, much better than single hyphae; and their vitality is such that old, dried rhizomorphs, if brought into a moist atmosphere, can recommence growth and put out new branches even after some years.

Instead of uniting to form long, cylindrical root-like strands, the hyphae of some fungi join into large, solid, more or less rounded and sharply defined masses, known as "sclerotia". These masses are very long lived and resistant to adverse conditions; their cells become filled with stores of reserve food; they usually separate off from the mycelium and become isolated and free; and they can resume growth when conditions become favourable, giving either a new mycelium, or in many cases producing the reproductive stage of the fungus.

In the case of the important root diseases of rubber trees in Malaya, the following summary as to the formation of plectenchymatic tissues by the various fungi may prove of interest to investigators in other countries.

F. lignosus forms external plectenchyma in the form of typical rhizomorphs, but does not produce internal plectenchyma, in attacked roots.

G. pseudoferreum forms external plectenchyma as typical rhizomorphs, which commonly unite to form a continuous rhizomorphic membrane, with a somewhat thickened outer skin. It also produces internal plectenchyma (*a*) in the form of occasional thin plates of tissue in the diseased wood, and (*b*) in typical fan-shaped masses of tissue in diseased roots just beneath the external skin formed by the rhizomorphic membranes.

F. noxius has external mycelium but it is masked by consolidated masses of earth and stones around diseased roots, and so the formation of external rhizomorphs or membranes cannot easily be made out. Internal plectenchyma is formed in the shape of numerous thin plates of fungus tissue running through the diseased wood.

S. repens has internal plectenchyma only, which occur as rhizomorphic strands, and retain the appearance of typical rhizomorphs. Microscopic rhizomorphs ramify through the diseased cortical tissues. Macroscopical rhizomorphs grow between the wood and the cortex, and when found they are usually seen on the surface of the wood. Owing to the position in which they grow and having to withstand considerable pressure, they are flattened in form.

U. zonata has internal plectenchyma only in the shape of numerous, prominent black plates of fungus tissue in diseased wood. There is no external plectenchyma and no suggestion of rhizomorphs either externally or internally. The rhizomorphic structures developed in pure cultures of both *U. zonata* and *S. repens* have been mentioned above.

Classification of Fungi

The vegetative parts of fungi are comparatively simple in structure, but the reproductive portion is more complicated. In the higher forms, large numbers of varied and elaborate structures are built up by the ramification and intertwining of simple hyphae, when the reproductive phase is entered upon. The thin, simple brackets of *Fomes lignosus* and the thicker brackets of *Ganderma pseudoferreum* may be mentioned as examples, and these may be compared with the fructifications produced by an Agaric such as *Marasmius palmivorus* which causes a disease of the tapping panel. This again may be compared with the minute, reddish pustules or cases which form the perfect fruits of *Sphaerostilbe repens.* Simpler forms of fructification, i.e. structurally more simple, are formed in fungi, such as *Phytophthora palmivora,* where single cells at the tips of simple hyphae become swollen and separated from the main body of the hypha by a cell-wall. In these, spores are eventually produced by the division of the protoplasm.

The fungi are classified by the differences between their reproductive parts, as are all other large plant groups. The barest outline only can be given here. Fungi are divided into two large groups known as (*a*) *Perfect fungi*, (*b*) *Imperfect fungi*.

Group (*a*) is subdivided into three large sub-groups which can be distinguished by the characteristic type of the fundamental reproductive structures. Group (*b*) is large and very heterogenous, consisting of fungi which cannot be included in the former group, because the reproductive structures typical of the three large groups of the perfect fungi are not present or have not been found.

The three large groups into which the perfect fungi are subdivided are as under:

I. *Phycomycetes.*
II. *Ascomycetes.*
III. *Basidiomycetes.*

These names refer to the characters of the groups. The suffix *mycetes* indicates *fungoid*, so that the three terms may be rendered as *Phycofungi*, *Ascus fungi* and *Basidia fungi.*

The terms "phyco", "ascus" and "basidia" will be explained below.

Phycomycetes.—"Phyco" is a term signifying "*related to the Algae*", and this group comprises certain fungi which retain considerable resemblance to certain groups of Algae. It is subdivided into large sub-classes, the *Oomycetes* and the *Zygomycetes.* The lower forms of

fungi included in the *Oomycetes* show but little complexity of vegetative parts and may consist of a single cell only.

In the *Zygomycetes* the mycelium is usually well developed. The hyphae may be septate or non-septate. Reproduction may be brought about by non-sexual or sexual spores, the former being usually produced within differentiated portions of the hyphae, commonly occurring at the tips of branches, and termed *sporangia*. Again, in this class certain spores may be produced upon, or abstracted from hyphae, in which case the latter are termed *conidiophores*. It is common also to find motile spores, capable of active movement in water, formed for the purpose of reproduction. There are seven large orders in the *Phycomycetes*, of which only one, viz. the *Peronosporales*, is of special interest, because it contains the genera *Phytophthora* and *Pythium*.

Ascomycetes.—The fungi included in this class have one common characteristic, viz. the *Ascus* or spore-sac, generally containing a definite number of spores (ordinarily eight). Many varied types of asci are produced; they may be of a comparatively simple type closely resembling a simple sporangium. In many orders of this class, the asci may be formed within a bed of modified mycelial tissue, which is termed a *stroma*. But the different types of ascus fruits are so diverse in form and consistency that it is not possible to pursue the subject; but throughout all these varied types of fruit-bodies the *ascus* or spore-sac, with its *enclosed* spores, is the characteristic feature. The number of spores may be less than eight but, if enclosed in an ascus, the fungus would be regarded as an *Ascomycete*. Again, there are numbers of fungi in this group having more than eight spores in the ascus, but in such a case the number is always some multiple of eight. The *Ascomycetes* contain a larger number of individual species than any other group of fungi. Conidial spore forms of manifold variety are known, and a single species may possess several conidial forms. The fungus causing mouldy rot is an ascomycete with two conidial forms. The mycelium is usually considerable, exposed or embedded in the substratum, and is septate. The fungi causing diseases in rubber plantations which fall in this class are *Ceratostomella fimbriata*, *Ustulina zonata* and *Sphaerostilbe repens*.

Basidiomycetes.—In general, the fungi included in this class are characterised by the type of fructification upon which the spores are developed. The form, size and shape of the fructifications exhibit great variation, but in every species the spores, four in number, are borne *externally* on the end of a swollen hyphal tip known as the *basidium*. The basidia are commonly closely crowded together to

form a definite layer known as the *hymenium*. The variation in the types of fructifications is well illustrated in the cases of *Corticium salmonicolor*, *Fomes lignosus* and *Ganoderma pseudoferreum*, all of which belong to the *Basidiomycetes*.

In connection with this large group, mention must be made of two rather anomalous groups usually included in it: (*a*) the *Hemibasidii*, (*b*) the *Protobasidii*. The former is of considerable interest; it contains only two families, all the individual species of which are obligate parasites. These are generally spoken of as the "smut fungi". The *Protobasidii* include the most important single order of plant parasites, the *Uredineae* or "rust fungi". Fortunately, the rubber plantations of the Middle East have never been troubled with attacks of smut or rust fungi, but the fate of the coffee plantations in Ceylon, which were devastated by the rust fungus *Hemeleia vastatrix*, is still well remembered by the older school of planters in Malaya, many of whom started their planting careers on the old coffee plantations in Ceylon.

For purposes of simplicity, attention has been drawn only to the spores of perfect and imperfect fungi, without mentioning the fact that the spores produced during the development of the perfect stage arise from the culmination of a sexual act, i.e. the union of two nuclei. The perfect spores, therefore, are the sexual spores. Put shortly, spores of imperfect fungi are asexual spores. The nature of the sexual process is most clearly shown in the *Phycomycetes*, and if we consider the fungi directly concerned with rubber tree diseases, *Phytophthora palmivora* and *Pythium complectens* best show the special features. Fig. 34 (*b*) shows the smaller, male cell, the *antheridium*, closely adpressed to the larger, passive female cell, the *oogonium*. The nucleus of the antheridium passes over into the oogonium, comes into contact with its nucleus, and the union is completed when the two nuclei become completely merged with one another to form a single nucleus. It will be understood that the sexual process, carried through by a smaller, active male element and a larger, passive female one, is strictly comparable with the sexual act carried out in much more highly organised plants and animals. Although a form of fertilisation occurs, these features of the sexual act are not so clearly seen in the *Ascomycetes* and *Basidiomycetes*. It is well established that the formation of perfect fructifications in the *Ascomycetes* is initiated by the union of sexual nuclei, and it has also been fully proved for the rust and smut fungi, which are classed as somewhat anomalous forms of Basidiomycetes.

Fungi Imperfecti.—This group of fungi constitute a heterogenous

subdivision of the true fungi. The individual species pass their reproductive phase without the development of the structures found in the groups discussed previously. But many of these types may represent stages in the life cycles of the perfect fungi. However, until the perfect form of the fungus has been definitely established, the enormous number of secondary fruit forms cannot be classified except by creating this special, though very heterogenous group. Families such as *Gloeosporium*, *Cytospora*, *Ascoshyta* and *Diplodia* are included in the order, and these will prove of some interest because species of these families are associated with certain diseases of rubber trees.

The large class of *Fungi Imperfecti* produce external spores which are budded off from more or less free hyphae and show no special arrangement as in the case of basidia (see Fig. 59 (*d*)). These spores are termed *conidia*, and the hyphae upon which they are developed *conidiophores*. Attention may be directed here to the asexual spores produced during the life cycle of *Ceratostomella fimbriata*. This fungus produces two distinct forms, which can be distinguished by the differences in wall thickness and the speed at which they are produced. But both forms are alike in that they are formed *endogenously*, i.e. within the hyphae, and are extruded at the tip, which opens as spore formation is in progress. These spores are spoken of as *endospores*, and are not commonly formed as compared with the external spores which are simply abstricted or budded off by the large majority of fungi.

Before spores can germinate successfully the requisite conditions must be satisfied. When optimum conditions are provided, the method of germination is similar in practically all cases, despite the varied methods appertaining to the initiation and production of fungus spores. A simple protrusion of one or more germ-tubes takes place, and as they increase in length branching begins, and after a time the elongating fungal filaments begin to ramify and intertwine with one another to form the vegetative portion of the fungus, the *mycelium*.

CHAPTER III

PHYSIOLOGY OF FUNGI

Saprophytism and Parasitism—Spread of Fungi—Immunity, Resistance and Susceptibility to Disease.

SAPROPHYTISM AND PARASITISM

ATTENTION has already been directed to the fact that the fundamental distinction between the fungi and all other plant groups is that they do not possess chlorophyll and so are unable to utilise the sun's energy in the matter of food synthesis. Therefore the carbon dioxide of the atmosphere is not available for the construction of the food materials necessary for their growth and development. As this source of carbon is denied to them they obtain it from organic combinations, and hence they are always associated with dead or living organic matter. In order to obtain the food material necessary for existence, fungi must break up complicated chemical compounds into much simpler forms. Carbohydrates form the principal and most important food material for fungi and these are broken down by the action of chemical substances known as *Enzymes*.

The enzymes are peculiar in that they are able to bring about the decomposition of certain constituents of the medium without undergoing any chemical change themselves, merely acting in an activatory capacity. The behaviour of an enzyme is different from that of an ordinary chemical agent, since the latter bring about alterations in other groups of atoms by their chemical affinity, so that the old combination is broken up and the separated portion enters into a new atomic grouping with a part of the active agent. Accordingly, a definite weight of the agent can only displace a definite quantity of other compounds, whereas in respect of enzymes their activity is *practically illimitable*. They do not combine with the products of the reaction but continue to react on the residual, undecomposed substance. The reason for the important part played in industry by large numbers of fungi is that they often possess specific enzymes which influence chemical changes in a certain direction.

Fungi are divided into two classes according to their mode of life. Those living on decaying vegetable matter are termed *Saprophytes*, while others which obtain their food material from the bodies

of living organisms are termed *Parasites*. As regards the nutrition of fungi, we must, as with green plants, distinguish between the process of assimilation, i.e. the conversion of the absorbed food substances into body substance, and that of respiration, i.e. the varied phenomena of decomposition and degradation due to the vital activity of the organism. Just as in green plants, the two processes are intimately related to one another, but during the respiration of fungi, a large number of different nutritive materials are transformed, the final products being carbon dioxide and water. Speaking generally, one may assert that constructive activity predominates during the nutrition of green plants, whilst destructive activity predominates in the case of fungi; the enzymes, which are of such general occurrence in the fungi, are the special destructive factors.

With regard to parasites and saprophytes it should be realised that there is no sharp line of demarcation between the parasitic and saprophytic habit. Some fungi, which attain to their best development as parasites, are able to maintain themselves, and undergo a portion of their life cycle in a saprophytic manner. The converse is also true. Thus, four subdivisions may be recognised physiologically. These are listed below:

(*a*) *Obligate parasites.*
(*b*) *Obligate saprophytes.*
(*c*) *Facultative parasites.*
(*d*) *Facultative saprophytes.*

The fungi classed in (*a*) can only maintain existence upon other living organisms as they are entirely dependent upon them for the requisite conditions for growth.

The fungi classed in (*b*) can grow only on dead organic material, being quite unable to penetrate living tissues.

The fungi classed in (*c*) are saprophytes, which occasionally, usually under very special conditions, may become parasitic.

The fungi classed in (*d*) are those which normally pass through life as parasites, but which are capable of maintaining existence for a certain length of time in a truly saprophytic manner.

Parasitic fungi can be subdivided into:

(i) *Holoparasites.*
(ii) *Wound parasites.*

The terms are self-explanatory. Fungi in (i) can make a direct attack on the plant; those in (ii) can gain entry into the living organism only through wounds. Attention may be directed here to the diseases

of the tapping panel. The act performed in obtaining the latex by tapping gives the opportunity for the entry of certain wound parasites, so that in the ultimate, the rubber tree, after being opened for tapping, must be considered to be in an abnormal condition, from a disease point of view. As a result of the possession of an adequate repair mechanism, no serious damage is done when normal tapping systems are used.

SPREAD OF FUNGI

The common method of spread is by means of spores developed in the special structures termed fructifications. In general, the statement may be made that spores are usually developed in large numbers by fungi, and in enormous numbers by some species, more especially by *Basidiomycetes*. Air currents play the most important rôle in the dissemination of the spores. But while air dispersal forms the general method there are many exceptions to the rule, as is well instanced by the diseases of rubber trees. In the case of the fungi causing panel diseases, viz. *Phytophthora palmivora* and *Pythium complectens*, spread is brought about by free-swimming spores and therefore can only take place in the presence of moisture, though a thin film only is required. The spread of the fungus causing mouldy rot, *Ceratostomella fimbriata*, from one district to another which may be distantly separated, is brought about by spores which are carried on coolies' clothing and implements, such as tapping knives. In the case of *Ustulina zonata*, which fungus produces a flat fructification with a copious development of conidia on the upper surface, it is quite possible that insects, in passing over the fructifications, would carry spores away on their various appendages. In the case of the fungus causing pink disease, *Corticium salmonicolor*, it is probable that dispersal of small flakes of bark carrying minute portions of viable mycelium is largely responsible for its spread. The rhizomorphs developed by the various fungi causing root diseases of rubber trees, more especially in the case of *F. lignosus* and *G. pseudoferreum*, provide a method of vegetative spread which functions most efficiently when root-contact between neighbouring trees has become established, and as a result these fungi may travel from one diseased tree to numerous healthy ones.

Large blocks of agricultural land planted up with but a single crop provide the most favourable conditions for encouraging the spread of disease-causing fungi. It is generally understood, and need not be dwelt upon here, that the host range of a parasitic fungus is usually limited. In numerous cases a fungus is limited to one particular host.

Of the fungi causing root diseases of rubber trees, *Fomes lignosus* has been reported as being found on large numbers of host plants, while similarly the host range for the fungus causing brown-root disease, *Fomes noxius*, is a wide one. The host range for *Ganoderma pseudoferreum*, on the other hand, is comparatively very limited, only a few plants up to date having been reported as hosts. The chief point is that in a plantation all the trees are largely of similar constitution, and if a certain parasitic fungus is present and conditions are suitable for its growth and spread, there can be no guarantee that any particular tree in the plantation will escape attack. This point may be emphasised in connection with the future planting-up of high yielding material, vegetatively propagated, more especially in monoclone planting. All the individual trees in such blocks of rubber will be more closely related to one another than the trees planted in the past and present stands of mixed plantings. Consequently, while the latter may be considered *largely of similar constitution*, the trees propagated from a single rubber tree must be considered to approach much nearer to the ultimate end, i.e. *an identical constitution*. There is little doubt that the possibility of epidemic disease is much increased when bud-grafted trees are planted in monoclone blocks. It is recognised that individual trees might show varying degrees of susceptibility to attack or that there may be trees which show complete immunity under the prevailing conditions, but in general, and confining remarks to rubber plantations, it can be stated with some degree of conviction that every tree in the plantation is subject to invasion by disease-causing organisms, more especially with such types as represented by the fungi causing root diseases. If this statement is accepted, it is obvious that, as the change from balanced jungle conditions to plantation conditions is made, there are ever-increasing chances of a serious spread of disease. In the jungle, with a thoroughly well-mixed stand of different species of trees, each individual or small group of a particular species is separated from others of the same species by plants of probably several different species which are not susceptible to attack by the particular fungus. The simplest case is that provided by a fungus such as *Ganoderma pseudoferreum*, which spreads chiefly by contact of the roots of a diseased tree with those of healthy trees. It is obvious that, under jungle conditions, root-contact between plants of the same species is extremely unlikely, except in localised places where a small group of plants of one particular species might have become dominant. Thus, under jungle conditions, a fungus such as *G. pseudoferreum* would develop in certain areas to form a "knot" of infected ground, and the spread

of the fungus would be confined within this knot. But on felling the jungle and planting-up a susceptible crop, every individual tree being, theoretically, equally susceptible, it is obvious that spread of the fungus will be encouraged to a practically illimitable extent. Thus the collection of plants, which have previously existed singly or in small groups, into large blocks of cultivation, is one of the most important factors to take full consideration of in connection with the spread of plant diseases.

The important root diseases of rubber trees need mention at this point. When the jungle is felled, the stumps of the trees are usually left *in situ*, to undergo natural decay. These decaying stumps support a very varied, usually saprophytic, fungus flora, but a few species may exhibit parasitic potentialities for developing and extending upon introduced plants. As the stumps decay but slowly, there are favourable possibilities of infection of the cultivated plants when they exist over a long period of years as permanent crops. As experience has shown in Malaya, the type of disease set up in such circumstances is usually more serious in early than in later years, and as the years pass the disease continuously decreases in intensity if adequate control measures are undertaken.

The characteristic knots of infected jungle areas are notably well shown in young rubber plantations in the case of *Fomes lignosus* and *Ganoderma pseudoferreum*. These fungi, in the jungle, may be comparatively rarely seen and may cause but little damage, but when exceptional advantages for extensive spread are offered in young clearings, they quickly become prominent and demand attention. Similar remarks apply to the attacks made by white ants.

Immunity, Resistance and Susceptibility to Disease

A large amount of literature dealing with the wonderful results obtained by the breeding of resistant strains of cereals and other annual crops in common use as food supplies, must have come to the notice of all laymen during recent years. A clear conception of resistance and immunity is seldom obtained by the rubber planter, for the subject is not a simple one, and as there are few features directly concerned with rubber cultivation, there is little opportunity allowed for close contact. A few short remarks only will be attempted in this book.

Immunity can be considered as the complete development of resistance. Resistant strains, varieties or species of cultivated plants have usually been discovered by chance, growing amongst a crop of

individuals some of which are infected by a particular disease. The resistant strain is then propagated and if the desirable disease-resistant properties do not interfere with other highly desirable properties required in the profitable production of the crop, which is not always the case, then the resistant line may be successfully developed on a large scale. But resistance must not be regarded as fixed for all and every set of conditions. If conditions are materially changed, resistance may break down and the plant would become susceptible once more.

It is an obvious truism that strong, healthy plants will be developed only when they are grown under favourable conditions. As a result, a certain amount of disease resistance may be provided. But this statement must be modified to some extent according to the crop and the requirements thereof. For instance, the view that high-yielding rubber trees are more susceptible to brown bast disease is commonly held. There may be doubts as to this but a definite statement can be made, viz. that on poor types of soil, where the growth conditions for rubber trees are undoubtedly unfavourable and low yields are a direct consequence, cases of brown bast are seldom seen. However, a congenial situation will usually confer on plants some general power of resistance against disease attacks. There is no doubt that if unsuitable conditions are avoided and agricultural practice is kept up to the requisite standard, then the dangers of serious plant disease outbreaks will be considerably lessened.

The aspects of the subject are innumerable and it would not prove profitable to dwell at length on any particular phase in this book. An extract from a recent address by Brown [1] may prove of interest as illustrating the extremely wide scope of this interesting subject, although, in the past, it has but touched the fringe of the disease problems encountered on rubber plantations in Malaya.

The subject of disease resistance in plants, considered from the point of view either of academic or practical interest, is of too wide a scope to allow of adequate treatment in such an address as I propose to give. Relevant material could probably be culled from almost any paper dealing with a plant pathological subject. There is the variation of susceptibility from one plant or variety to another and the different behaviour of the same plant under different environmental conditions. Viewed from another standpoint, there are such matters of interest as the pathogenic range of various fungal parasites and the differences in virulence shown by strains, biological races, etc., of the same fungal species. Data of this type would all contribute to make up the full story of disease resistance, but

[1] Brown, W., 1934. "Mechanism of Disease Resistance in Plants." Pres. Address. *Trans. Brit. Myc. Soc.*, vol. xix. Part I.

it is doubtful if any summary, covering the whole field, could be usefully attempted on this occasion. For those of you who might wish to read more generally on the subject, a number of papers might be cited, e.g. by Marshall Ward and Appel among earlier writers and more recently by Brooks and Walker. To the last mentioned I would specially refer you for a good and comprehensive catalogue of the types of relationship shown in parasitism.

The variation of susceptibility in varieties of single species is mentioned in the above extract. There are certain indications in Malaya that varietal disease susceptibility will need consideration in connection with bud-grafted plants. Two clones showing definite susceptibility in certain directions have been observed. Young trees of clone B.D.5 show susceptibility to lightning damage. This is attributed to the particular form developed by the young trees. The individuals of this clone have a late branching habit and, compared with trees of other clones of the same age, attain a considerable height before branching. It is suggested that owing to the long, unbranched stem, the trees of this clone attract lightning more readily. It will be difficult to prove the point, but there does not appear reason to doubt the fact that in this clone there is a preponderance of lightning damage.

A much clearer case is reported on page 411. In 1932 three estates reported the same feature. Areas of mixed clones were damaged by the short-horned grasshopper, but only the individuals of the clone A.V.R.O.S.256 were attacked, and large numbers suffered complete defoliation, while all other interplanted clones escaped attack.

There remains one item which deserves mention, and that is the question of disease caused by fungi introduced from another country. Many of the most serious epidemic plant diseases have originated as a result of an introduced parasite to which the particular crop has not been previously exposed. To further the prevention of the introduction of possible harmful fungi from outside, most countries with large agricultural interests now have rigid quarantine rules for imported material. Malaya cannot afford to be an exception. The absence from the country of the fungus causing South American leaf disease is in itself enough to demonstrate this statement.

It will also be appreciated that, in introducing plants intended for cultivation from countries abroad, indigenous fungi might find them very suitable hosts on which to maintain existence. In such cases also, very serious plant diseases may originate.

CHAPTER IV

EXTERNAL FACTORS AND RUBBER TREE DISEASES

Outside Factors influencing Rubber Tree Diseases—Tapping Systems and Panel Diseases—Disease Symptoms in Rubber Trees.

OUTSIDE FACTORS INFLUENCING RUBBER TREE DISEASES

THE study of the host plant under cultivation introduces numerous complications into disease investigations, many of which are of the utmost importance; they often receive attention, however, only in a generalised sort of fashion. The importance of outside factors as they influence plant diseases has been generally recognised, as the following extract from an address given by Brooks in 1923[1] will indicate:

> Plant pathology is essentially abnormal plant physiology, in which a parasite is often the disturbing agency. Acting upon both host and parasite are environmental conditions which sometimes favour the one and sometimes the other. As Butler has indicated in his *Fungi and Disease in Plants*, these external factors are often of critical importance in the establishment of disease.

The most important fact to note in the above statement is its qualified nature. With respect to the cultivation of the rubber tree and the diseases from which it suffers, the writer would withdraw all qualifications and definitely state that external factors must always be given an important place in the initiation and continuance of all serious outbreaks of the more important diseases.

For the purposes of agricultural practice, the important distinction in relation to plant diseases may be set forth in the form of the general statement made by Nowell, viz. as between those diseases which develop upon plants in normal condition, and those which occur to a serious extent only upon plants reduced in vigour by unfavourable circumstances, such as soil and climate, insect infestation or methods of cultivation. The various items mentioned in this general statement are well recognised in so far as they do exert a considerable influence on the course of specific plant diseases; but in spite of this, it is doubtful if sufficient attention has been devoted to

[1] Brooks, F. T., 1923. "Some Present-day Aspects of Mycology." Pres. Address. *Trans. Brit. Myc. Soc.*, vol. ix. Parts I and II, Sept.

this aspect of disease investigations, more especially when permanent or semi-permanent crops are under consideration. It is important to recognise that while normal conditions for growth may be provided at the outset, natural phenomena may bring about important changes in the growth conditions, so that they may become abnormal and may ultimately favourably influence the invasion of the crop plants by parasitic organisms.

In the special case of rubber cultivation an attempt will be made to show that the plant pathologist cannot legitimately attach greater importance to the organism causing a disease, or to the host plant, than he can to the factors which influence the reactions of both. This fact emerges more plainly to the observer whose activities are mainly confined to the investigation of one particular crop. Malaya proves a very suitable country from this point of view, for the agricultural interests of the country are mainly bound up in the cultivation of rubber. All other Eastern countries growing rubber have large interests in the production of several different types of primary produce, and these crops demand attention, in addition to rubber.

Nowell's statement may be accepted as a starting-point for the discussion to follow. To avoid diseases, plants must be kept in normal condition, which implies that normal growth conditions must be maintained. The conditions represented in the soil, and those of climate, are of the greatest importance, and if these remain constant, or around the optimum, within the higher and lower limits representing normality, the plant will retain the normal condition, usually most antagonistic to injurious influences.

It will be obvious that soil conditions will remain comparatively static as compared with climatic conditions; the latter undergo quick and often abrupt changes. On the point of changes in soil conditions, it will be interesting to institute a comparison between temperate and tropical countries. In the former, permanent tree cultivations are seldom commenced on virgin jungle soil; the soil benefits by the annual return of organic material in the shape of fallen leaves, and in the practical cessation of all vital activities, including water absorption, during the wintering period. Both the trees and the soil in which they exist have a favourable opportunity for recuperation during the winter period in temperate climates, and some definite benefit must result in both cases. The only injurious influence which is likely to affect the trees seriously during the winter resting periods is intensive freezing.

The rubber areas in Malaya were mainly started on recently felled jungle areas, which can be considered fairly rich in humus material

available as plant food. But given this advantageous commencement, neither the soil nor the trees planted have much opportunity for recuperation by the interspersion of a well-marked annual resting period—the important favourable factor for plant development in temperate climates. The rich humus content of the original jungle soil is provided by the thick, shrubby natural undergrowth prominent in Malayan jungles, and once the light conditions are changed by the felling of the jungle, the plants of importance in the formation of humus disappear. As the jungle soil is comparatively favourable for the growth of the rubber tree in the early years, and as clean weeding operations favoured the supervision of labour, the latter operation became popular and firmly established in the early days of rubber planting. Although leaf-fall occurs on rubber plantations, it is in most years very irregular in Malaya, and as already stated there is no decided resting period. It may be taken for granted, therefore, that rubber trees, as cultivated in Malaya, are characterised by an uninterrupted growth period and that there is a practically continuous drain put upon the soil for the supply of food material. Thus, although virgin jungle soil may confer an initial advantage, the changes which take place in it soon become evident, and if plants of normal health are produced at the outset, they cannot maintain this condition if the soil changes indicated take place rapidly. This is generally the case, especially on hilly land, when no measures are taken to prevent soil erosion. It will be obvious that, unless measures designed to keep the soil up to the original standard are undertaken, the conditions for outbreaks of plant diseases become more favourable as the years pass, because of deleterious soil changes brought about by natural factors working over a long period of time.

So far, it has been assumed that all jungle areas in Malaya would prove equally suitable for growing plants in normal condition. This is, however, far from being the case, because the areas of land which could be considered first-class for rubber cultivation form only a very small proportion of the total. In all prosperous agricultural industries the best sites are sought for and taken up first, and these are likely to be the only ones which will form first-class properties. It is not, of course, always only the type of soil which determines choice of site, for locality and probable costs of transport are of importance from the point of view of costs of production. Again, if old cultivated areas with permanent buildings are available there is every reason why such areas should be considered for rubber cultivation, for there should be knowledge available as to whether the soil would prove suitable or not. While these considerations must be taken into account,

the time inevitably comes, if the industry continues to prove prosperous, when only ill-balanced soil areas are still available for planting-up and the prosperity of the industry overrules any doubt there may be regarding unsuitable growth conditions. After a period of time, therefore, areas partially, if not wholly, unsuitable for the purpose in view are used for extending the area under cultivation, and according to the type of crop, the plants in these areas are very liable to contract disease, as compared with plants grown on the better areas. Once disease-centres become established there is little possibility of predicting the ultimate outcome. Rubber cultivators are fortunate that *Hevea brasiliensis* can be grown successfully under conditions showing very wide variations, a feature which accounts for the widespread range of many weeds. It is not too much to say that rubber trees show many of the characteristics of weeds. They have this in common: both are extremely difficult wholly to exterminate, even when growing under conditions obviously unfavourable.

The above indicates that permanent tropical crops, such as rubber, can seldom be grown in habitats providing continuous conditions for ideal growth which are necessary to maintain continued health. The position might be better stated by saying that in rubber cultivation innumerable chances arise for the successful development of disease-causing organisms, even if conditions for normal growth of the host plant are provided at the outset. Slow deteriorative changes in soil conditions and quick changes in climatic conditions are taking place constantly, and these changes bring about lasting effects on the growth conditions of the plants under cultivation, which can have but one outcome, viz. that the plants will become more liable to attacks from disease-causing organisms.

Up to this point, an endeavour has been made to state the case in the simplest possible way. The gradual changes in soil conditions with time, and the abrupt changes which may take place in climatic conditions, will be readily understood. Periodic changes in climatic conditions, which constitute an annual feature extending over a short period of time only, will not disturb the normal condition of the host plant to any great degree, if the fluctuations are confined within certain limits. But in Malaya, during certain years, the short, annual wintering period, during which conditions for growth may be considered comparatively unfavourable, may be prolonged unduly, and the normal condition of the rubber plants might be expected to undergo some change. The change is not necessarily immediate and any external change may not, in a permanent crop, become apparent for some time. In such circumstances, cause and effect are difficult

to associate with one another, but when disease symptoms are observed and fungi happen to become prominent, they are commonly considered to have played a part of primary importance as the cause of the trouble; indeed, it is not uncommon for them to be considered solely responsible. The position outlined above will, in the writer's opinion, ultimately be shown to be an outstanding feature in the case of lightning strikes on rubber plantations. The immediate damage done may be easily recognised in the trees affected, but the later effects which follow, on trees apparently unaffected in the first place, have not yet been closely followed up. These deferred results have been demonstrated clearly in connection with lightning damage in coconut plantations, and it is extremely likely that similar conclusions will be reached in rubber plantations with further work.

Brierley [1] states the position very clearly, though in rather technical language, as follows:

> It will thus be evident that the complete understanding of a case of ill-health involves the genetic and physiological analysis of both host and parasite, and the physical and chemical analysis of the conditions under which both organisms have developed and at present exist. In actual practice one can only adopt a Baconian technique and rejoice if any single factor can be isolated and examined. Such investigations necessarily can only give very partial views, and a real comprehension of any particular case, considering the case of disease as an individual entity, requires that such partial views be synthesised as separate photographs are merged in a cinematograph film. An investigation of a disease is, as it were, a cross section of a process that is essentially a continuum, and a serious danger in plant pathology to-day is the tendency to accept isolated studies of a disease at any one moment as a true picture of the whole.

The only observation the writer wishes to make on this quotation refers to the last paragraph. Studies of a plant disease in the tropics must necessarily be commenced on a line which would form an isolated unit. A danger certainly lies in the liability of an investigator feeling satisfied that the isolated study provides the true position of the whole, but this in fact seldom happens. Investigators engaged on phytopathological problems in the tropics have not usually the opportunity to carry on a line of work beyond certain limits. There are usually a superfluity of problems requiring attention, and as shortage of staff is commonly the limiting factor in every projected research, it is seldom that any investigator can commence a line of work and expect to carry it through successfully to completion.

A detailed physical and chemical analysis of the climatic conditions

[1] Brierley, W., 1924. "The Relation of Plant Pathology to Genetics", *Report of Proceedings, Imp. Bot. Con.*, p. 112.

in Malaya and other rubber-growing countries in the Middle East cannot be provided here. It will be sufficient to indicate the main features of the climate in Malaya and to call attention to some of the larger differences in climate existing between the different countries concerned, more especially in respect of the wintering seasons and the monsoon periods, in so far as they affect the disease position.

Practically little of the rubber area in Malaya is affected by the onset of monsoon periods. The state of Kedah and a small area in Upper Perak is influenced by the North-West monsoon about February each year, but the only significant item is that they pass through a relatively long, dry wintering period at this time of the year, as compared with other rubber-growing districts.

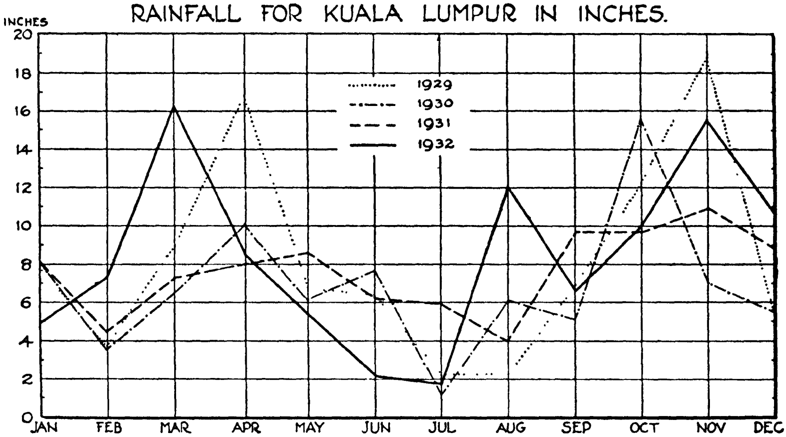


DIAGRAM I

The uniformity and high humidity of the climate in Malaya is particularly noticeable. The only pronounced seasonal variations are those connected with rainfall. This is well distributed throughout the year, but has a distinctly higher incidence during the two periods April–May and September–December. Between these two periods there is a tendency for more open dry weather to occur, centring around February and July–August. The dry period centring round the month of February is usually considered to be a short, very dry period, compared with the longer but wetter period of July–August. The annual main wintering of the rubber tree coincides with the onset of the dry weather period in February. The advent of a sufficiently lengthy period of dry weather results in a regular wintering

through which more than half of the trees are leafless about the same time. In Malaya such winterings are the exception rather than the rule. Usually, occasional wet days or a succession of wet days interfere with the defoliation process and the wintering becomes very irregular with some trees leafless, others partially defoliated and others fully clothed with leaves. It is estimated that in most years, about 15 to 20 per cent of trees do not winter in February, but carry over to winter in the later dry season around August, when a small secondary wintering takes place. An even wintering period, comprising a long drought period, is viewed with considerable anxiety, for yields drop to comparatively low levels and there is a risk of serious damage being caused by the outbreak of leaf fires. Further, a wintering period may be experienced, during which the succession of rainless days may be broken by days on which light showers occur. Light showers of rain, occurring during a wintering period which for a certain length of time previously has been excessively dry, result in the refoliation process proceeding at a comparatively slow rate, and this feature provides ideal conditions for a virulent outbreak of *Oidium* leaf-fall.

In Ceylon the sequence of events is somewhat similar, excepting that the May–July period is influenced by the breaking of the South-West monsoon, with the advent of very heavy rains, which are practically continuous over a long period. Petch reports as follows:

In the principal rubber districts of Ceylon, *Hevea* sheds its leaves at the end of January or early in February in the low country, and a few weeks later at medium elevations. Frequently, apparently more especially when, instead of the normal drought, heavy rains occur in January and February, the wintering is irregular. Neighbouring trees may winter at periods differing by two or three weeks, and even one side of a tree may drop its leaves and acquire new foliage before the leaves on the other side have commenced to change colour. In this normal leaf-fall, the leaflets are usually disarticulated and fall first, while the leaf-stalk remains attached to the branch and only falls later.

With reference to Java, the writer is indebted to the Director, Proefstation, West Java, for information. Correspondence in relation to the disease caused by *O. heveae* passed between the Proefstation and the Rubber Research Institute of Malaya, and the following details were provided:

When considering the occurrence of *O. heveae* in connection with the climate of Java, you should bear in mind that, generally speaking, we have three different climates here. There are striking differences between the west, the middle and the east of Java. Even in the case of West Java

proper you cannot compare the estates on the west slope of the mountains with those situated on the east side. Moreover, in successive years great differences occur in the intensity of the monsoons. I think that this explains the conflicting information brought to you from Java.

The information given below refers to West Java only: (1) The actual time of wintering and refoliation runs from the middle of July to about the end of September. (2) The dry weather period begins in the month of May. As a rule, June and July are very dry. Then, beginning about the second half of August, rainfall is gradually increasing. November may be very wet. The wettest month, however, is January. (3 and 4) Unlike Malaya and N.E. Sumatra, there is only one dry season in Java. Accordingly a second wintering season is unknown here. (5) *Oidium* attack may be serious on estates above 200 metres. The higher the estate the more serious the attack. (6) Rainfall occurs in August and September chiefly during the late afternoon and the early hours of the evening. The number of rainy days varies considerably for the different localities.

We read with great interest the article entitled "The Effect of Meteorological Factors on the Virulence of *Oidium heveae* in Malaya", and the facts concerning the optimal conditions for the growth of *O. heveae* are in good agreement with our own observations on this subject.

Climatic conditions often vary greatly in different countries which grow the same crop. In the rubber-growing countries of the Middle East the greatest difference lies between those countries directly affected by the rainy monsoon period and those which are slightly or even unaffected by monsoon periods. Even in the same country, the influence of the monsoon periods may bring about very different results from the disease point of view, on the crops cultivated, according to the topography of the country. This is well indicated in the copy of the letter given above, referring to cultivated areas in Java. A great influence on diseases of the rubber tree is exerted by the heavy and continuous rains which fall during the S.W. monsoon in Ceylon and S. India. Serious outbreaks of *Phytophthora* leaf-fall, which happen only during these wet spells in the countries mentioned, are entirely absent in Malaya; at least, the most important rubber-growing districts in the country are entirely unaffected by the monsoon periods. Continuous high rainfall results in a constant high humidity, and this factor greatly increases the dangers from potential outbreaks of disease.

The topography of a country naturally affects climatic conditions. Close proximity of plantations to the sea, where land and sea breezes are in daily evidence, has many advantages from the disease point of view. Ventilation is a potent factor towards reducing a high degree of humidity, and therefore daily winds will go a long way towards rendering climatic factors innocuous in the causation of disease. The

presence of high mountain ranges has a profound influence on plantations as regards disease incidence, and it will usually be found in such situations that there are certain diseases of common occurrence which are not found in other districts in the same country. In fact, the limitation in area of any plant disease is practically a sure sign that climatic conditions are exerting an influence of magnitude in these areas.

The most convenient method of presenting details of the effects of outside factors upon disease problems in the rubber plantations in Malaya will be to classify the various factors as under:

(1) Outside factors influencing the important root diseases.
(2) Atmospheric agencies.
(3) Meteorological factors influencing stem, branch and leaf diseases.
(4) Factors, including meteorological ones, affecting panel diseases.

Outside Factors influencing the Important Root Diseases.—The most important root diseases to be considered in this section are those caused by fungi of the *Fomes* type. This subject is dealt with in detail in the root-disease section and ample proof is there provided for the conclusion "that the three root diseases caused by *Fomes lignosus*, *Ganoderma pseudoferreum* and *Fomes noxius* and the problems they present, are entirely dependent upon the type of vegetation grown previously upon the areas now under rubber". This statement will fully meet the position at the present stage, and the further remarks which remain to be made will refer to the disease caused by *Sphaerostilbe repens*. There is no definite information available relating to outbreaks of this disease beyond the fact that they are invariably associated with damage caused by the flooding of rubber areas. Most investigators agree that outbreaks are dependent on some unknown predisposing factor or factors, and of these flooding is apparently the chief. Up to date none of the numerous investigations undertaken on parasite or host have yielded any information of sufficient value to draw a definite conclusion. I am informed, however, by Dr. S. F. Ashby, that the association of the *Sphaerostilbe* disease with flooded areas is a noticeable feature in certain areas in the West Indies.

Atmospheric Agencies.—A whole section is devoted to this subject, under the heading "Scorching and After-effects". The direct effects of lightning on rubber plantations, only definitely established over the last two years, form the most important item.

Several observers, including Petch in Ceylon and Maas in Java, have briefly described the varied types of damage caused on coconut

palms and rubber trees by direct lightning strikes. But there was little information available in respect of any crop, until the writer proved beyond doubt that lightning was the primary cause of practically all apparent disease outbreaks on coconut plantations in Malaya. When it was possible to focus attention on Malayan rubber plantations, the important effects of lightning became more noticeable each year as additional experience was gained. The year 1933 was noteworthy for the large number of reports of lightning strikes on rubber plantations. The most important feature is the close association of lightning injury with patch canker at the collar of the tree. Further, the species of *Diplodia* causing "die-back" is always a prominent feature whenever scorching of the trees takes place, and there is now not much doubt that many of the early reports of branch damage, etc., with die-back supervening later, were merely descriptions of lightning effects.

Attention is also directed to scorching effects caused by agencies other than lightning, There can be no opposition to the view that in cases where the direct effects of atmospheric agencies are obvious, the associated fungi must be given a secondary place.

Meteorological and Soil Factors affecting Stem, Branch and Leaf Diseases.—The rubber tree diseases which call for attention under this heading are (*a*) pink disease, (*b*) *Oidium* leaf-fall, (*c*) minor leaf affections. The *Phytophthora* leaf-fall as it occurs in Ceylon and S. India will also be referred to.

The early experiences of pink disease in Malaya indicated that there was no reason why this disease should not spread throughout all the rubber-growing areas in the peninsula. The difficulties of accounting for the distribution of the disease was pointed out in 1913, and the statement was made that the disease was most abundant in the districts of heaviest rainfall and where large tracts of jungle remain. The distribution in 1913 is given on page 268, and the position is described in the following words: "But it is only in certain localities, where climatic conditions favourably affect the growth and spread of the fungus, that serious attacks occur. . . . In Malaya, it might be said that all estates where serious attacks of pink disease occur are situated in proximity to large jungle reserves." In the writer's opinion, this is the most important feature in respect of attacks of pink disease, even at the present date. It is still confined to particular localities, but these change with time since the causal fungus is seldom prominent on areas carrying trees over ten years of age. A relatively high humidity will be maintained on young rubber areas completely surrounded by jungle because advantageous wind

breezes will be prevented from reaching them, and so effective ventilation will be prevented. This in itself will make the conditions exceptionally favourable for disease-causing fungi, and the cause of pink disease evidently finds them very favourable. It is a well-known fact that pink disease is of little importance and is seldom seen on coastal properties affected by daily variations in land and sea breezes. Judging from studies of distribution it cannot be doubted that, when serious attacks of pink disease occur, factors outside host plant and parasite are mainly responsible.

The effects of external influences on the *Oidium* leaf-fall disease is dealt with fully in the section devoted to leaf diseases, and the results obtained in Malaya over the last few years prove beyond doubt that climatic factors play by far the most important part in the initiation of serious outbreaks. The same statement applies to this disease as it occurs in Java, as indicated by the letter received from the Director, Proefstation, West Java. A further point of interest is that when serious outbreaks of *Oidium* leaf-fall are reported in Malaya, the areas which show the worst affection are those where the soil is in poor condition through comparative exhaustion. Here again an example is presented of the potent influence exerted by unfavourable soil conditions in the successful development of a particular disease.

The *Phytophthora* leaf-fall reported from Burma, S. India and Ceylon is often referred to as "monsoon" leaf-fall, and the trees begin to shed their leaves about a fortnight after the monsoon rains have set in steadily. But Petch records that in 1917 and 1918 the first cases of leaf-fall occurred at the end of January, long before the onset of the monsoon rains, and that the periods mentioned were characterised by abnormal heavy rains in some districts instead of the usual dry weather and, as a result, one or two cases of the disease appeared. It is apparent that the appearance and continuance of the disease is entirely dependent on long-continued heavy rains, and the absence of this disease from Malaya can be attributed to the fact that, even during the heaviest rain-periods, there are daily bursts of sunshine which effectually prevent the development of those fungi which spread by means of free-swimming spores, such as species of *Phytophthora* and *Pythium*. If climatic conditions proved suitable, there is no reason why rubber areas in Malaya should not suffer from attacks of *Phytophthora*, for Thompson has proved conclusively that there are, in Malaya, a considerable number of species, some of which would undoubtedly cause a leaf-fall under suitable climatic conditions.

The only subject of interest remaining for consideration is that

of the minor leaf affections. These probably form the best examples of the effects of unsuitable soil conditions, and it is doubtful whether they would be noticed at all if soil conditions were normal. This feature is well understood by planters in Malaya and is only mentioned here for the sake of completeness.

Factors affecting Panel Diseases.—There is little necessity to go into details respecting the influence of external factors upon the fungi causing tapping panel diseases. The following points may be stated briefly:

(*a*) The operation of tapping results in the development of a tree which must be considered as *not in normal condition*. Neither black stripe, brown bast nor mouldy rot diseases would have the slightest significance but for the tapping operation.

(*b*) Black stripe and patch canker are caused by fungi producing free-swimming spores. The effects of daily bursts of sunshine in Malaya, upon this type of fungus, has been mentioned above.

(*c*) Recent experience with mouldy rot in field experiments has proved that the humidity of the atmosphere exercises a profound effect on the development of the causal fungus, and this instance provides the clearest example for the writer's view that external factors can be considered of almost primary importance in most of the important rubber tree diseases in Malaya. Development of the fungus in the field is severely checked, if not entirely suspended, when a short, hot dry period of only forty-eight hours is encountered; at least all external signs of the fungus, which are always conspicuous under ordinary conditions, may totally disappear. Taking the reversed condition, if the atmospheric humidity in diseased areas is increased, as would be the case if a natural cover of a mixture of plants were established under mature rubber trees, as is recommended by advocates of forestry methods, it becomes practically impossible to control the spread and development of the fungus. Methods of treatment which have proved wholly successful when diseased trees are growing under the common methods of cultivation, are useless.

Before leaving this subject, the various points might be summarised so that the essential facts clearly emerge. The writer wishes to emphasise that the facts demonstrated must not necessarily be taken to apply in rubber plantations outside Malaya. They must be considered by competent authorities in other countries, and tested how far they apply to their own problems, and if climatic and other external factors show a considerable degree of similarity there is little doubt that the picture displayed in this section will be found worthy of careful consideration.

The following points give shortly the gist of the position:

(1) Root diseases are entirely dependent on the type of vegetation grown previously on the rubber areas.

(2) All fungi associated with damage brought about by direct atmospheric agencies must be classed as of secondary importance.

(3) The successful initiation and continued development of the important leaf and branch diseases is largely dependent on congenial outside factors; serious outbreaks of the important leaf-fall diseases caused by *O. heveae* and *P. meadii* respectively would never occur except under special climatic conditions, and in the case of the former, unsuitable soil conditions exert a significant influence in outbreaks of the disease, just as in the case of the minor leaf affections. These would seldom be observed if soil conditions were normal and permitted the optimal development of the trees.

(4) Outbreaks of panel diseases occur only because of the method of extracting the latex. Nevertheless, climate has a great influence, and if climatic conditions prove unsuitable to the free development of the causal fungi, serious outbreaks are seldom observed. In the case of the most serious panel disease of rubber trees in Malaya, i.e. mouldy rot, the extraordinary rapid disappearance of all the external signs of the fungus, when a short burst of sunny, dry weather occurs, indicated very clearly that the disease can only assume serious proportions during periods when atmospheric humidity is high.

The subject has been dwelt upon at considerable length both here and in the preface. It only remains to be said, when undertaking investigations on cultivated crops in the tropics, it should never be forgotten that it is "the disease as it appears in the field" which is the important feature. Once this is fully realised, the importance of all factors outside host and parasite will receive the quota of recognition which seems so desirable.

Tapping Systems and Panel Diseases

During the period *circa* 1910–12, and up to about 1920, which were prosperous years for the industry, when the price of rubber was still above the $1 per lb. level, the primary idea which guided the industry in the selection of a tapping system was to obtain as much latex as possible from the tree; the suggestion that over-extraction of latex would predispose the trees to certain diseases naturally received very minor consideration. Thus, in 1910, ladder or monkey tapping, with several superimposed cuts over half the circumference

of the tree, was commonly practised. In later years the practice became less frequent, and by 1916–17 two superimposed cuts on half the circumference was considered the limit; the vertical distance between the cuts varied. In the early years the cuts were started about a foot apart, but in later years the distance was increased so that the cuts were started about two feet apart. About 1917–20 the brown-bast scare supervened, and as the fact was gradually driven home that brown bast is a physiological affection which is initiated and maintained by over-extraction of latex, tapping systems, less drastic in operation, had to be considered very seriously.

It was shown conclusively that, from the disease point of view, alternate daily tapping held an advantage over daily tapping. As any diminution of output occasioned by the adoption of an alternate daily tapping system could be compensated for by increasing the length of cut, no profits were lost unnecessarily. Alternate daily systems, over one-half or one-third of the circumference, were the systems most commonly adopted in Malaya, and these have retained their popularity to the present day; it is estimated that 30 per cent of the rubber trees in Malaya are still being tapped on an alternate daily tapping system.

About 1922–23, tapping systems, based on a periodical cessation of tapping, were being experimented with. One of the first was termed the A B C daily tapping system, over one-half the circumference, for a period of twelve months; this meant that each block was tapped daily for a period of eight months and the trees were then rested from tapping for a four-months period. This system did not prevail long, for attacks of black stripe and brown bast became common after about three months' daily tapping, on estates where panel diseases had never been recorded previously. A similar result has been obtained experimentally in relation to brown bast, where it has been shown that under daily tapping systems bursts of disease activity occur at intervals of three to four months.

Since 1931, tapping systems have been considered from one point of view only, that of economy. One system which has been introduced recently is known as the alternate monthly; the trees are tapped once daily over half the circumference for a month, then tapping is stopped for a month. This system undoubtedly encourages the growth and persistence of the fungus causing mouldy rot, for estates which have adopted this system are now finding mouldy rot more difficult to control than was the case formerly. There is sufficient evidence available to warrant the statement that, in Malaya, vigorous trees are unable to withstand more than three months' continuous daily

tapping before showing attacks of panel diseases. Generally, it can be definitely stated that all daily tapping systems, with a length of cut greater than a quarter of the circumference of the tree, predispose the latter to the onset of panel diseases.

Cessation of tapping during treatment of diseased tapping areas is a factor of the greatest importance. It is absolutely vital in the case of brown-bast treatment, and of fundamental importance in the treatment of mouldy rot; in Malaya, cessation of tapping is not of such great importance in the treatment of black stripe. But a recommendation to cease tapping for a longer or shorter period has never been a popular one at any time. It is obvious that, during prosperous periods, the output should be kept as high as possible in order to augment profits, and, therefore, as many trees as possible should be kept in tapping. This argument is countered by the fact that it is a foolish policy to risk permanent damage to valuable trees by continuous tapping while in a diseased condition. During periods of depression, the case is somewhat different and the situation cannot adequately be met. Since 1931, up to the present date (1933), Asiatic owners have been forced to tap their trees daily to obtain supplies of food, and the question of disease treatment is pushed into the background; indeed, it may be said that the pests and diseases enactment becomes inoperative in Asiatic-owned plantations in Malaya during slump periods. On European estates, selective tapping has been adopted on most estates and only those trees which give an adequate flow of latex are tapped. As trees suffering from panel diseases usually give a diminished flow of latex, they are automatically left out of the tapping round.

Now that a policy of restriction of output has been inaugurated, the cessation of tapping diseased trees becomes a subject of direct practical interest. It would be of direct benefit to the industry and also to the restriction policy if cessation of the tapping of such trees could be made compulsory. The machinery for doing so is already established. It is not, however, within the writer's province to pursue this matter further, but it may be commended to the authorities engaged in carrying forward restriction proposals.

Disease Symptoms in Rubber Trees

The reactions of the rubber tree to attacks of the various diseases from which it suffers may be briefly commented upon. The visible reactions are generally confined to the stem and crown portions of the tree, owing to the fact that the ultimate action of disease-causing

fungi on the rubber tree is to cause a diminution in the water supply to the above-ground portions. When the water supply is reduced beyond a certain limit to any particular part of the crown, the leaves affected are bound to wither and die. Thus, the direct response to an attack of root disease, which causes a reduction in the area of the root-absorbing system, is reflected in the crown by the death of the leaves and branches.

The leaf reaction to root attack may be very different, however, according to the age of the tree and vigour of the fungus attack. It has been shown very clearly, in Malaya, that the two most important fungi causing root diseases are both present in the early stages of the plantations, i.e. infected plants are to be found when the plants are about one and a half to two years of age. The attacks of *Fomes lignosus* are comparatively sudden in onset and in intensity, and it usually reaches its apex in the fourth or fifth year; although even in later years the disease may still be prominent if the necessary precautions have not been observed. Usually, the attack commences to wane about the fourth year and the disease should be well under control by the sixth year. With *Ganoderma pseudoferreum*, on the other hand, though the fungus is present in the original jungle, it gets little opportunity to spread from the primary centres until the roots of the rubber trees begin to make definite contact, and as its progress is definitely slow, it does not become very prominent on rubber plantations until towards the tenth year.

While the symptoms of both diseases are primarily caused by the reduction in the water supply below a certain level, owing to the roots being killed, yet owing to increased tissue development in root, branch and leaf systems of the older trees, the response in the crown is very different in the two diseases. If we consider the crown of a young tree as equivalent to one branch of an older tree, then there is no real relative difference. In the young tree attacked by *F. lignosus* the crown of leaves continues to develop until the reduction in the amount of water from the roots to the leaves is felt; they suddenly wilt and in a few days they turn brown and fall off the tree, leaving bare branches. On the other hand, in the disease caused by *Ganoderma pseudoferreum*, the reduction in the amount of water supplied by the root system can only take place slowly, owing to the reaction of the roots to attack by this fungus. Attacked roots throw out enormous numbers of healthy, absorbing, adventitious roots (Fig. 19 *a-d*). Although the fungus usually wins in the end, such an artificial increase in the root-absorbing system results in a very slow reduction in the water supply to the leaves. Thus, there is a gradual diminution in

the leaf canopy, but the leaves produced at the tips of large branches become of smaller dimensions as the years go by, and finally large branches may become leafless. Mature trees, showing leaves of less than average size and large dead branches on one side of the tree, may usually be suspected of being attacked by *G. pseudoferreum*.

In general, the above description may be said to apply to all root diseases of rubber. The symptoms may be not quite so definite as in *G. pseudoferreum*, and in the case of *Sphaerostilbe repens* they may be obscured by the entrance of boring beetles at the base of the stem. Following the comparison made between the crown of a young tree and the branch of a mature tree a step further, the symptoms of pink disease in advanced cases may be considered as brought about by a reduction in the water supply to a localised portion of the crown. Die-back disease falls in the same category. In both cases the fungus destroys the continuity of the large wood vessels in the periphery of the woody cylinder, which are most active in water conduction, and so this function cannot be performed efficiently. The leaves and woody twigs and branches above the attacked areas are denied a sufficient quantity of water for the metabolic processes to continue normally, and therefore death ensues.

In the case of attacks by *O. heveae*, the interference with water supply is of paramount importance, but in rather a different manner. It is generally held that the autumnal fall of leaves from plants growing in temperate climates is a response to the reduction in the supply of water caused by the change in weather conditions; water absorption by roots is greatly reduced by low temperature, and so during winter months the quantity of water absorbed is comparatively small in amount. The action of *O. heveae* on leaves of rubber trees is to break up the continuity of the cuticle and epidermis of the leaf so that water evaporation, which is controlled by the stomata in the epidermis of the leaf, is greatly increased. Owing to the increased loss of water through the leaves, the physiological balance between the leaves and roots is badly upset and, as a result, the former are abstricted in a young, green condition and fall to the ground; in this way, excessive loss of water is for the time being avoided.

In brown bast, the water balance in the cortical tissues is of the utmost importance. This disease is now considered to be a physiological affection brought about wholly, or in the main, by over-extraction of latex, the water content of which is about 60 per cent under normal tapping systems. When trees are over-tapped, the usual result is a percentage decrease in solid constituents and a consequent rise in liquid content, so that still higher percentage losses of water

must take place. It is obvious that if such a situation is allowed to develop, the balanced condition of water relationship in the cortical regions must be upset, and this loss of balance is reflected in the symptoms of brown bast.

The panel diseases may all be considered from the opposite point of view, for as a result of the parasitic activity of the fungi, only local areas of bark are affected, and the transport of elaborated food materials in these diseased bark areas will be interfered with. Of course, in cases of neglect, large areas of bark may be put out of action, and the damage done in such circumstances must be serious.

PART II

FORM AND FUNCTION

CHAPTER V

PLANT FORM

Stem and Root Structure—General Remarks on Leaf Structure.

STEM AND ROOT STRUCTURE

FOR the special purpose of this book it is considered desirable to give an outline, in the form of a very general account, of the tissues of the stem and leaves of a mature tree and to indicate the physiological activities with which they are connected. The terms covering Form and Function are *Morphology* and *Physiology* respectively.

In order to study the morphology of any part of a plant thin sections of tissue have to be cut in certain definite planes. These sections are spoken of as: (*a*) Transverse sections, (*b*) Longitudinal Radial sections, (*c*) Longitudinal Tangential sections.

The transverse section is self-explanatory; it is simply a cut made in the horizontal plane (Fig. 1).

The longitudinal radial section is a vertical cut, which is made in a plane along a radius of a circular stem from the centre to the periphery (Fig. 4).

The longitudinal tangential section is made in a plane which is a tangent of the radial plane and cuts across the radii of a circular stem (Fig. 5).

All planters are aware that the stem of a rubber tree is composed of a central cylinder of hard, woody tissue surrounded by a softer cylinder of cortical tissue, which is covered externally by the corky bark. Between the inner cylinder of hard, woody tissue and the outer cylinder of cortical tissue, there is a single cell layer which is constantly dividing and giving rise to new tissues, both internally to the woody ring and externally to the cortical tissues; considerably more tissue is cut off internally to form additions to the wood than to the outer cortex. The tissues composing the cortical portions can be distinguished as being formed of two parts, an inner portion nearest the

cambial layer, i.e. the inner cortex, and an outer portion which comprises all the tissues between the inner cortex and the outermost bark layers, i.e. the outer cortex. The latex containing cells are found in the inner cortex, usually very near the cambium.

The study of Fig. 1 will clearly show the various tissue systems mentioned above. This photograph is one of a transverse section of a small root, but it can be taken as typical for a section of a stem. Apart from certain differences in the actively growing regions and in the portions where active absorption of water from the soil is taking place, the roots are similar to stems in cell structure. Growth in roots is carried forward by active division of cells at their extremities, and in this region they are very sensitive and so require protection when making progress amongst the soil particles. Protection is provided by the development of a covering layer, termed the *root-cap*. The growing points of stems during development do not meet with obstacles of similar nature as the growing points of roots, so there is no necessity for constant protection by means of a protective covering layer, and nothing of the nature of a stem-cap is developed. In the roots, some of the epidermal cells, i.e. those of the external layer, in the absorbing areas, grow out and form elongated, hair-like growths, which are termed *root hairs*,[1] and these form the actual absorbing organs of the root system. The stem is different in structure in this respect because its function is not one of absorption. It is only in these two particulars that the root and stem structure differ materially. There is a definite distinction in the arrangement of the primary groups of wood, known as "protoxylem groups", in stem and root, but this feature need not be enlarged upon in this book.

The illustrations show that the various tissue systems are composed of cell elements, very diverse in character. But the original cell-walls of all the individual cells in any tissue system are composed of the same material, i.e. *cellulose*. As growth and development takes place various secondary substances are deposited on the original cellulose walls, and by this means hard, woody systems, or softer cellulosic ones, are brought into being.

The inner, woody cylinder is composed of varied cell elements, but the most important constituents, physiologically, are the large cells termed *Vessels* (Figs. 1, 2 and 3).

The vessels are long, undivided tubes which are devoid of protoplasm and are therefore dead, their main physiological function being the transportation to the leaves, of water and nutrient materials absorbed by the roots. It is only the outer, recently formed vessels

[1] See "Root Hairs" in Glossary.

that are functional; a certain time after formation, vessels thicken, lose their functional capacity of water conduction and are then

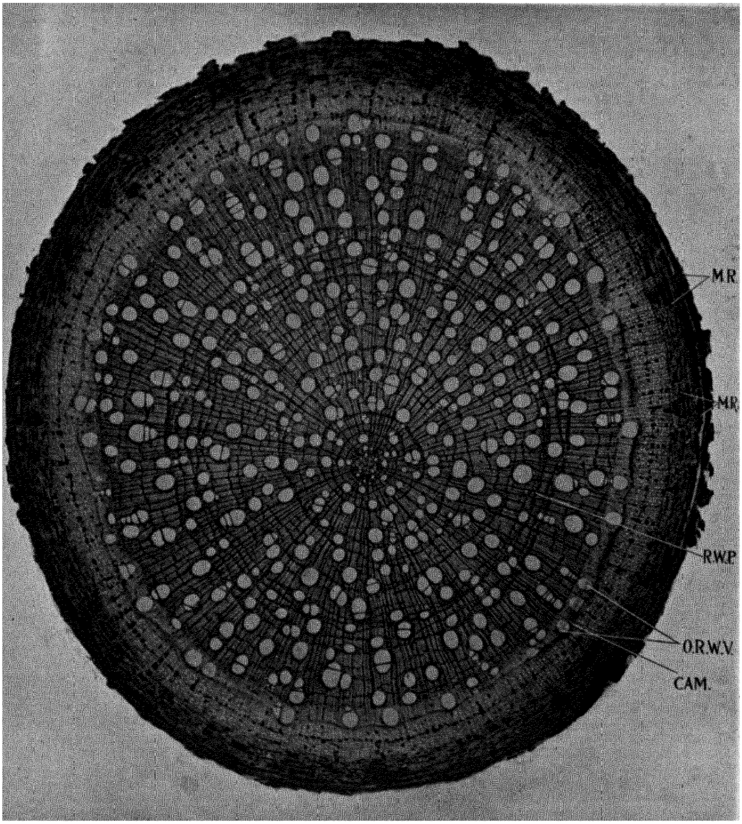


Fig. 1.—Transverse section of small lateral root of *H. brasiliensis.*

Note.—Extent of woody vascular ring, the most prominent component part being the large water-conducting vessels. External ring of large vessels indicates outer limits of vascular ring, which impinges directly on the cambial ring. (Fig. 2 shows an enlargement of cambial region.) Outside the cambium or cambial ring lies the inner and outer cortical layers, together forming the cortex. The cortical layers are bounded externally by the epidermis.

R.W.P. = Rings of wood parenchyma showing as irregular rings in the vascular ring. They appear as dark rings because the cells are filled with starch grains.
M.R. = Medullary Rays running radially from outer cortex through inner cortex and cambial ring to varying depths in vascular ring. The portions indicated by M.R. show the rays spreading out in the outer cortex to assume a fan-shaped appearance, commonly seen in woody plants.
O.R.W.V = Outer ring of wood vessels.
CAM. = Cambium, immediately exterior to O.R.W.V.

replaced by the vessels developed in the new wood, which is being formed continuously during the growing season by the actively

dividing *cambium*, situated between the woody cylinder and the cortical tissues. The woody cylinder is characterised by the deposition of a substance called *lignin* on the original, cellulose cell-walls, and this substance stains red with a dye named safranin. The technical term used for all the woody cells comprising the woody cylinder is *Xylem*.

The *cambium* is a single layer of actively dividing cells, upon which

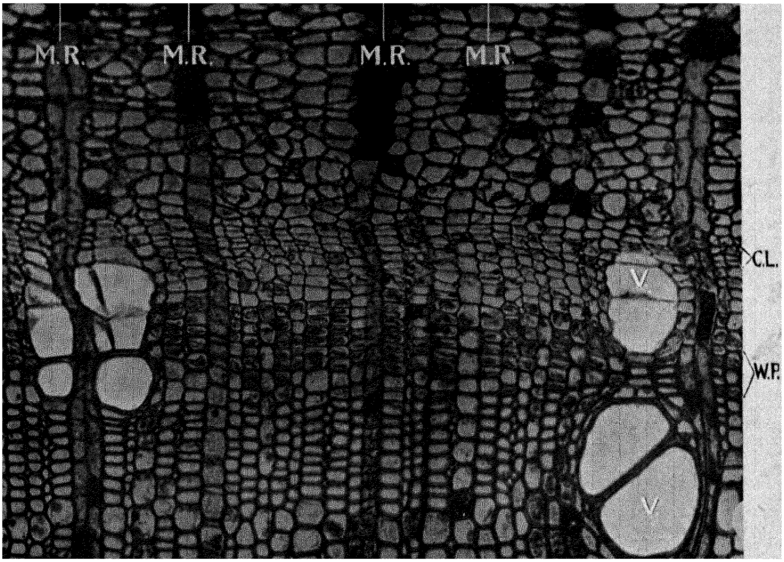


FIG. 2.—Enlargement of portion of transverse section of woody stem of *H. brasiliensis*, showing cambial layer (C.L.), with large wood vessels impinging directly on these actively dividing cells internally. The cells which divide off externally to the cambium, form parts of the cortex.

The medullary rays (M.R.) are well shown to be continuous, passing from the cortical areas, through the cambial layer, into the woody, vascular cylinder. A single zone of wood parenchyma cells (W.P.) is shown, but this does not show up so conspicuously as those shown in the transverse section of the root (Fig. 1), because the individual cells do not contain starch grains in such large numbers. ×120.

all parts of the plant which undergo increases in girth are dependent for expansion (Figs. 2 and 3).

Apparently, the illustration in Fig. 2 shows more than one layer of cells which might be engaged in active division. These appear to be four to six layers and, to avoid confusion in the layman's mind, these layers of cells form what is termed here, the cambial layer. The cambial layer comprises all those cells recently cut off by the single layer which is actually dividing. New cells cut off by the cambium are

small, and growth leading to maturity results in the increase in size. But until full size is attained, they appear to form part of a definite layer composed of cells much smaller than normal fully grown ones, and they are arranged in radial rows. This radial arrangement is characteristic of all cell systems formed by cambial activity. Cells are

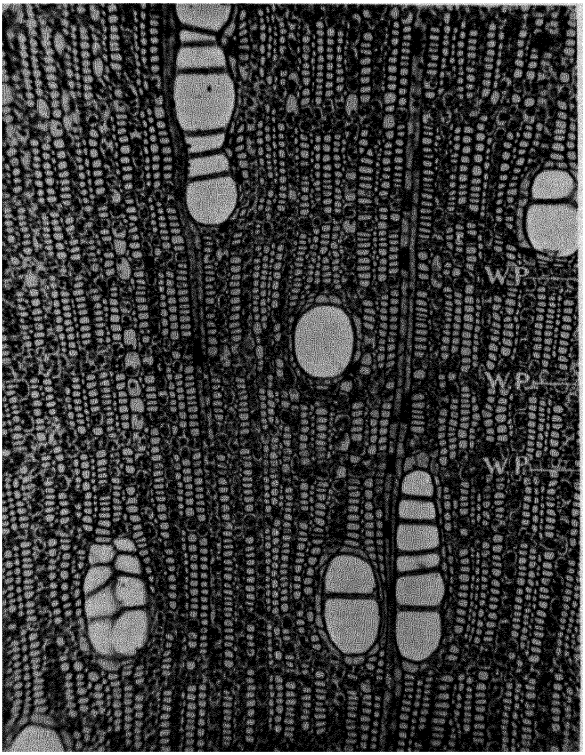


FIG. 3.—Enlargement of portion of transverse section woody tissue of vascular cylinder, showing typical appearance, in transverse section, of large water-conducting vessels, and zones of wood parenchyma (W.P.). × 120

cut off by the cambium on the inner side to become wood or xylem elements, while cells cut off externally become bast or *Phloem* elements. The walls of the phloem elements, in general, retain their original, cellulosic character; as they age, they become thicker as a result of the further deposition of cellulose. Cellulose stains blue with a dye such as haemotoxylin.

The most important cell elements in the phloem system are the

Sieve Tubes, their main function being to transport food materials elaborated in the leaves, downwards to all parts of the plant. The transverse walls which divide the length of a sieve tube are of a special nature and perforated, and are termed *Sieve Plates*. The ring of wood, plus the cambium and the phloem, form the *Vascular Cylinder*.

A transverse section through the stem of a plant, one year old, will show that the thickness of the cortical tissues outside the cambium, i.e. the phloem and the remainder of the cortical tissues, is comparatively small in extent compared with the woody ring or xylem tissue developed within the cambial ring. A similar section through the stem of a tree ten years of age will show a still larger discrepancy in favour of the woody ring. This is accounted for, not only by the fact already mentioned that more xylem than phloem elements are formed as a result of cambial activity, but also that the cortical tissues are being sloughed off continuously as bark. This is brought about by a cambium, termed the *Phellogen* or cork-forming cambium, which is laid down in the external cortical layers; division in this layer takes place in such a way that the great majority of new cells arising from the activity of the phellogen come to lie externally to it, and the walls of these cells become impregnated with a substance termed *Suberin*. This is a waterproofing substance and such cells are said to be suberised; the waterproof layer formed by the aggregation of these corky cells is the true bark.

Two actively dividing, or meristematic layers have now been mentioned, *the* cambium forming the xylem tissues of the internal woody ring and the external cortical tissues, and the cambium forming the outer, corky, bark layers. There is a distinct difference between these two meristematic layers, for the cambium between the cortex and the wood is a permanent tissue-forming layer and it persists throughout the life of the tree; the cork cambium forming the bark, however, is replaced from time to time, after cutting off the external layers of cortical cells to form bark, by the formation of additional, successive, deeper-seated cambial layers, and these, in turn, cut off the tissues external to them. Thus, bark is not formed as a product of a single, persistent cambium, but from a succession of meristematic layers or cambia, formed at gradually increasing depths in the cortex.

There is another type of cell, known as *Stone-cells*, usually developed in groups in the cortex. Planters are well aware of the difference between hard-barked and soft-barked trees. Normal yielding trees are usually characterised by a cortex which is sufficiently soft to allow the tapping knife to pass through without difficulty. Hard-

barked trees are not tapped easily, because there is only a comparatively thinly developed cortical region, which contains a large proportion of cells which become thickened by deposits of lignin; in other words, they become lignified and form stone-cells. These cell-walls are often thickened up so strongly that the lumen of the cells are practically obliterated. It will be remembered that lignification characterises the formation of woody elements.

Thus far, in dealing with a woody stem, the upward flow through the wood vessels of water and nutrient materials absorbed by the roots and the downward flow of elaborated food materials from the leaves, through the sieve tubes, has been mentioned. Water and elaborated food materials must be transported to all parts of the plant, and as the vessels and sieve tubes are located in definite, stationary positions, a conducting tissue system, suitably placed for radial conduction, seems necessary, if a complete circulatory system is to become established. This is provided by a system of cells known the *Medullary Rays*. These pass radially right through the wood, starting at varying depths, and through the cambium into the phloem elements and the cortical tissues (Figs. 4 and 5). Secondary or new medullary rays are constantly being laid down by the cambium as development proceeds.

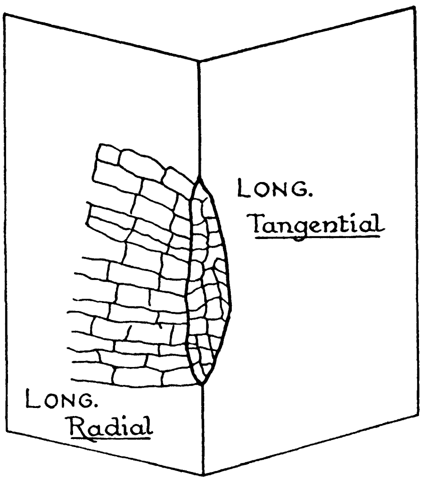


DIAGRAM II
Medullary ray in combined L. Tangential and L. Radial section. To amplify Figs. 4 and 5.

The above is a very elementary and abridged account, but sufficient, it is hoped, to prove useful to the layman in enabling him to realise the terms attached to the elements forming the conducting systems, and the fact that these latter form a complete circulatory system within the plant. The illustrations will be of interest to show the typical features of plant structure seen in a woody stem when sections are studied under the microscope. It should not be assumed that the circulatory system is in any way comparable to that in the animal organisation, where there is a central organ

which forcibly pumps the blood-stream through the largest arteries to the tips of the smallest veins. The circulation of water and elaborated food materials in plants is dependent entirely on purely physical forces, i.e. diffusion, osmosis, etc. This is a very complicated field and no point would be usefully served by entering into further description or discussion.

The foregoing remarks apply generally to the great majority of

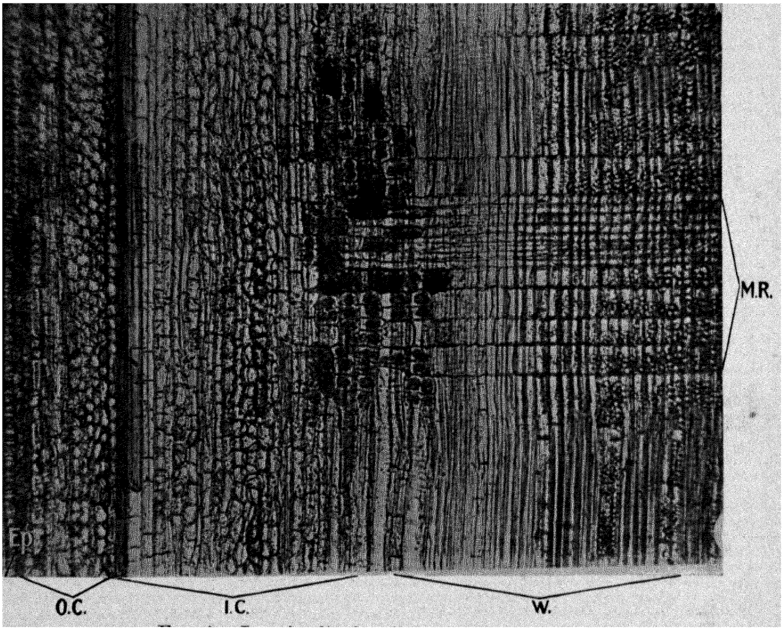


FIG. 4.—Longitudinal radial section of stem.

Showing epidermis (Ep.); outer cortex (O.C.); inner cortex (I.C.); wood (W.); and medullary rays (M.R.), running radially from wood to cortex or vice versa.

Note.—The actual line of demarcation between the various tissue systems is not well shown in radial sections and the areas indicated must be considered to be merely approximate. × 120.

woody plants which do not produce latex. In *Hevea* the latex is found in a tubular system, the elongated tubes or *Vessels* being formed by the absorption of the end walls of individual cortical cells; the water-conducting vessels in the wood are formed in a similar manner. Unlike the latter, they are not dead elements, for the laticiferous vessels retain their protoplasmic lining, which proclaims them as living. The laticiferous system is an additional development to the normal cell systems found in other plants, and it is very doubtful if those which

have acquired a laticiferous system could continue to live without it, if it were possible to deprive them of it. The cell elements from which the laticiferous vessels in *Hevea* are formed are cut off by the cambium for the special purpose of latex formation in a very similar manner to the special cell elements of the cortex which ultimately form part of the special conducting systems, such as the sieve tubes and the

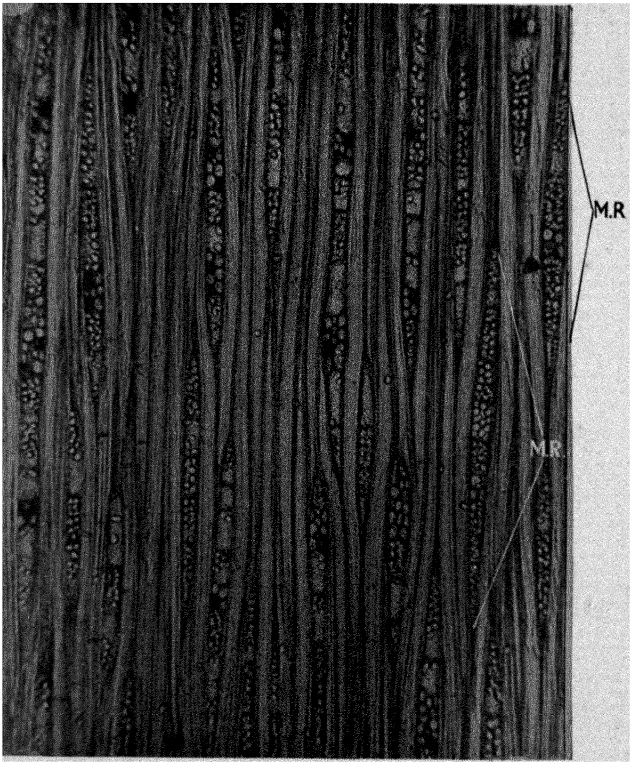


FIG. 5.—Longitudinal tangential section of stem, showing typical structure of medullary rays. × 120.

medullary rays. As the differentiation of the laticiferous elements takes place rapidly after they are cut off by the cambium, they become recognisable as such before they have passed far from the cambial region, and this explains why the main seat of the laticiferous system of *Hevea* becomes established in the inner cortical layers (Fig. 6). In the early days it was generally stated that the laticiferous vessels of *Hevea* ran more or less vertically up and down the stem,

but it is now generally accepted that they are definitely situated at a slight inclination to the vertical, running some 5° to 7° to the right of the vertical line.

For our elementary purpose, the plant world may be divided into two groups: (*a*) Laticiferous plants, (*b*) Non-laticiferous plants. The laticiferous plants form only a very small proportion of the great plant kingdom. They secrete the white fluid known as latex; this

FIG. 6.—Longitudinal tangential section through inner cortex, showing latex containing cells (laticiferous vessels), darkly stained.

Note.—The laticiferous vessels do not show up plainly when the usual cell wall stains are used, as in the preceding figures. A special stain to show up the cell contents of the laticiferous vessels has therefore been used in order to bring out the typical appearance of the latex system of *H. brasiliensis*. It is only the latex which takes up the stain, and the walls of the latex tubes cannot clearly be made out in this illustration.

substance may be contained either in laticiferous *cells* or laticiferous *vessels*. The method of formation of the latter has already been mentioned, and it is a system of laticiferous vessels which is formed in *H. brasiliensis*. Laticiferous *cells* are non-septate from the commencement and are formed as the result of the apical growth of certain cells which are differentiated in the seed. As the plants increase in size, a ramifying, branched latex system is built up by the apical growth and branching of the early differentiated, laticiferous cells. Species of *Euphorbia* show this type of development in their laticiferous systems.

It is quite safe to say, whether we consider laticiferous cells or vessels, that our ignorance of the functions of the latex system in any laticiferous plant is most profound. The latex vessels in *Hevea* are situated in close proximity to both the sieve tubes and the medullary rays. The main constituent of the latex vessels is water, about 60 per cent by volume under ordinary tapping conditions. The following figures give the results of a normal analysis; they may be somewhat approximate but will serve the purpose in view:

Water	Rubber (Catouchouc)	Protein	Ash	P_2O_5
Per cent 58–62	Per cent 39–40	Per cent 2–2·5	Per cent 0·60–0·70	Per cent 0·175–0·250

The high water-content of latex, as extracted from the tree, suggests that the laticiferous system of *Hevea* would act as a water-storage reservoir, given suitable conditions. This general view of the function of laticiferous systems in plants has been presented by many authorities; in support thereof is the fact that numerous plants of many different families grow under arid conditions, e.g. desert plants, and develop well-defined latex systems. But there is little definite knowledge on this complicated subject. Planters will note, however, that the extraction of latex includes the withdrawal of large quantities of water from the cortical tissues in the neighbourhood of the tapping-cut; thus the water relationships around the tapping areas, where tapping is in progress, must be very different from those functioning in the cortical areas of untapped trees.

It is unnecessary to pursue this question further, but there is one suggestion which has become firmly implanted in the mind of many planters, and that is, that the laticiferous system functions as a protective layer against insect attacks. The statement has been made on many occasions that white ants and boring beetles would not attack a healthy rubber tree. A categorical statement can now be made that this idea has been exploded, and there is not any semblance of a reason left to doubt the fact that white ants can directly attack healthy rubber trees. The position, with regard to the penetration of the cortical tissue by boring beetles, is substantially the same and is dealt with fully in the section dealing with insect pests.

General Remarks on Leaf Structure

Foliage leaves are very varied in structure, therefore these remarks must be confined to a generalised explanation of a common type of leaf.

Leaves usually show a clearly marked difference between the upper and lower portions, bounded by the upper and lower epidermis respectively. A diagrammatic section of a leaf is given below (Diagram III.).

A foliage leaf is bounded on all sides by a typical epidermis. The epidermis is usually formed of a single layer of cells. These cells

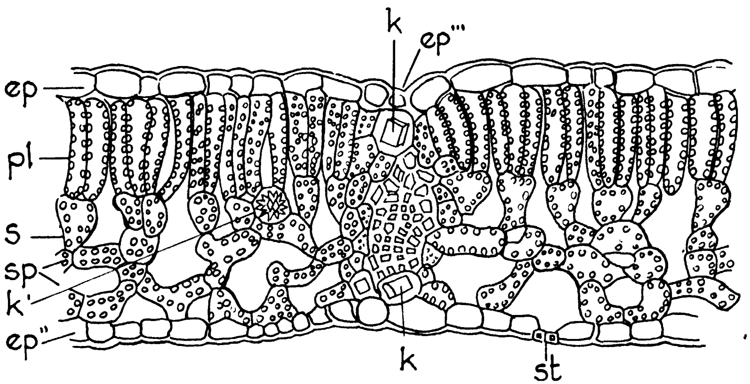


Diagram III

Transverse section of a leaf of *Fagus sylvatica.*

ep, Epidermis of upper surface; ep'', epidermis of under surface; ep''', elongated epidermal cell above a vascular bundle; pl, palisade parenchyma; s, collecting cells; sp, spongy parenchyma; k, idioblasts with crystals, in k' with crystal aggregate; st, stoma. (×360. After Strasburger.)

secrete a substance known as *cutin*, and a transparent continuous layer, known as the *cuticle*, is formed as a result of the deposition of the cutin. The cuticle covers the aerial parts of the majority of herbaceous plants. Cutin is a substance which, chemically, is very impervious to water and a remarkably stable body, capable of resisting the action of various solvents which dissolve ordinary cellulose.

The leaves have often been referred to as the breathing organs of plants. If the respiration of plants (i.e. the exchange of oxygen absorbed from the atmosphere and the expiration of carbon dioxide (CO_2)) and breathing are considered equivalent terms, then the comparison is not entirely correct, for all parts of green plants, roots, stems, branches and leaves, respire. It will be quite correct to say that the leaves are of paramount importance in gaseous exchange

between the plant and the atmosphere; but this exchange includes not only the function of respiration, but also that of transpiration, i.e. the escape of water vapour from the plant to the atmosphere, and the very important function of carbon assimilation, i.e. the exchange of CO_2 absorbed from the atmosphere and the expiration of oxygen, all of which are conducted entirely through the leaves. This gaseous exchange conducted during the function of carbon assimilation is the exact converse of that concerned in respiration.

The leaves are enabled efficiently to perform these important phases of gaseous exchange because they possess a special type of regulatory mechanism in the shape of *Stomata* (*sing.* stoma). The stomata are situated in the epidermal layers, more especially on the under surface; they may be quite absent from the upper surface of the leaves in some plants. The stomata are, in fact, minute openings through the epidermis. These openings close automatically under certain conditions of light and humidity by the action of two *guard cells.* When the guard cells are turgid, i.e. full of water, the stomata stand open, and when turgidity is low in the leaves, the guard cells lose water, become less turgid, and the stomata then close and no further water vapour can be lost; neither can satisfactory gaseous exchange take place through them. The stomata average 100 to 300 per square millimetre, and in exceptional cases they are as numerous as 100 to 700, and may even reach 2000 per square millimetre.

The stomata are of paramount importance for the efficient regulation of the gaseous exchange apparatus in plants. They are delicately responsive to changes in light intensity, opening wider as light increases, contracting as the light wanes. They are in direct communication with the large intercellular spaces found in the *spongy parenchyma,* i.e. the tissue found immediately above the lower epidermis of the leaf, and by means of these spaces the gases are distributed throughout the plant to all living cells. The plant is, in fact, riddled with a continuous system of these fine spaces. Even the cells farthest from them are distant not more than a few tenths of a millimetre from an air passage. This system of intercellular spaces provides for the quick diffusion of gases throughout the entire plant.

The tissue of the leaf-blade between the upper and lower epidermis and between the ribs or veins consists mainly of thin walled cells known as parenchyma and forms the tissue termed *Mesophyll.* The finer veins are embedded in it. Three different kinds of tissue can be differentiated in the mesophyll, as in Diagram III.

(*a*) *Palisade parenchyma,* underneath the upper epidermis, consisting of one to three layers of cells elongated at right angles to the

upper epidermis. They possess abundant chloroplasts which contain the green colouring matter known as *Chlorophyll* and have very narrow intercellular spaces between them.

(*b*) *Spongy parenchyma*, immediately above the lower epidermis, mentioned above; this layer consists of irregularly shaped cells with wide intercellular spaces and less chlorophyll than in the palisade tissue.

(*c*) *The Vascular tissue*, comprising the finer veins or vascular bundles.

The cells of the palisade tissue often converge in groups towards enlarged collecting cells situated between the upper palisade layers and the spongy parenchyma. These cells are sometimes known as the border parenchyma and form a sheath around the vascular bundles in the veins. The vascular bundles in the leaf-veins correspond on the whole to those seen in the stem, consisting of xylem, cambium and phloem, with the same arrangement of parts.

As stated above, the roots absorb nutrient materials from the soil, in watery solutions. This is transported through the young vessels of the xylem to the tips of the finest veins. In the leaves, concentration of the nutrient solutions takes place by transpiration. The concentrated nutrient solutions are then elaborated in the leaves into a suitable form for conduction and then transported to all parts of the plant, the most important route being the passage provided by the sieve tubes of the phloem.

CHAPTER VI

PLANT FUNCTIONS

Carbon Assimilation—Respiration—Transpiration; Water Absorption—Chlorophyll and Carbon Assimilation—Respiration and Liberation of Energy—Definition of Disease.

THE important functions in plant life are four in number. They are termed: (*a*) Carbon assimilation; (*b*) Respiration; (*c*) Transpiration; (*d*) Water absorption. Carbon assimilation and transpiration are carried on entirely by leaf activity; respiration is carried out by all parts of the plant, while water absorption, as is well known, is purely a function of the roots.

An endeavour will be made to give a simple outline of the somewhat complicated vital processes of carbon assimilation and respiration, phenomena about which misunderstandings may easily arise. No special mention of transpiration by the leaves or water absorption by the roots is necessary, as there are no phenomena concerned in these comparatively simple processes which demand explanation. The writer fully appreciates, however, the difficulties of explaining the factors governing the ascent of sap in tall trees which are bound up with these two latter functions, which are, in themselves, readily understood. A few concise remarks on (*a*), (*b*) and (*c*) above will now be made.

CARBON ASSIMILATION

Carbon assimilation consists of the exchange between carbon dioxide absorbed from the atmosphere and elimination of oxygen. This can only take place during the day, because the stomata close during periods of darkness and they form the main passage through which the exchange is made.

As a result of carbon assimilation by green plants, organic substances (e.g. starch) are manufactured from inorganic substances (e.g. carbon dioxide and water). Certain conditions are essential in order for the assimilation of carbon from the atmosphere to take place. Shortly, these are as follows:

(1) Light of sufficient intensity is required.

(2) Chlorophyll is necessary; this is not formed in the absence of oxygen. A sufficiently high temperature and a certain amount of iron

salts in the food are also necessities for the formation of the green colouring matter.

(3) If a sufficiently high temperature is necessary for the formation of chlorophyll, this also holds for carbon assimilation.

(4) Carbon assimilation, and the consequent formation of starch, does not go on if the cells are not supplied with potassium salts in solution. This can be easily proved by water cultures.

Respiration

Respiration consists of the exchange between oxygen absorbed from the atmosphere and carbon dioxide liberated by the plant. This function is continuous throughout the twenty-four-hour daily period and is independent of the opening or closing of the stomata. It may be directly compared with the process of breathing in animals. Respiration takes place even in the roots, and if the free supply of oxygen to these organs is interfered with, terrestrial plants die of root suffocation. It might be thought that these two opposite processes would balance one another; actually, however, carbon assimilation is far more rapid than respiration. During the course of a normal day, the plant absorbs considerably more carbon dioxide than it liberates and there is thus a balance of carbon in favour of the plant which goes to increase the weight of the plant body and of the manufactured foods stored therein. Further remarks on respiration are given later.

Transpiration

Transpiration consists of the elimination of water vapour from the leaves. While the stomata may not be wholly responsible for controlling the amount of water given off by the plant, yet when they are open a greater amount of water vapour would pass through them. It may be said that, in the main, stomatal transpiration only, is of importance in the typical land plant. It is usual, however, to distinguish between stomatal and cuticular transpiration. In some cases, when the water supply in the soil is becoming low, continuous transpiration might become a real danger to the plant, and the ability of the plant to retard transpiration under such circumstances would be a matter of vital importance.

Further remarks will be confined to two subjects: viz. (1) Chlorophyll and Carbon Assimilation; (2) Respiration and Liberation of Energy.

Chlorophyll and Carbon Assimilation

The palisade layers of cells, found immediately underneath the upper epidermis, form the main seat of assimilatory activity. The cells of this tissue are thickly stored with cell plastids termed chloroplasts, which are bodies containing the green colouring matter, chlorophyll. The cell plastids and the green chlorophyll are separable, for the green colouring matter can be dissolved out from the plastid by alcohol and they then appear as before, but devoid of colour. The significance of the chlorophyll is that it arrests a part of the energy of the sun and transforms it in such a way that the chloroplasts can use it in food synthesis. The chloroplast, a specialised, aggregated portion of the cell protoplasm, does this work, but to do this it needs to be energised by the sun, and apparently this is what the chlorophyll is instrumental in bringing about. As it is the sunlight which furnishes the energy for food construction, the process is called *Photosynthesis*. The amount of photosynthesis taking place is influenced by the light intensity, and it cannot take place in the absence of carbon dioxide. The temperature may rise too high or fall too low for the continuation of this function; in the higher plants, on account of their waterproof epidermis, photosynthesis must stop when a reduction in water-content in the cells of the leaves results in the closure of the stomata, for then the continued inflow of carbon dioxide is prevented.

The first *visible* food made by the chloroplasts from the carbon dioxide of the atmosphere and the nutrient materials absorbed by the roots is *starch*, in the form of minute grains. There is reason to believe that sugar is formed before the starch appears and presumably in the chloroplasts also, but it is soluble in the cell sap and probably does not long remain where it is first formed, but passes by diffusion from the chloroplasts into the cell sap that fills the cell cavity and then into the tissues devoted to food conduction.

The main facts regarding the leaf functions may be briefly recapitulated. The epidermis is transparent and lets light through. The chloroplasts in the palisade cells absorb light and use approximately 4 per cent of its energy in carrying on food synthesis. Light that escapes through the palisade parenchyma is arrested so completely by the spongy parenchyma tissue that not enough goes through the leaf to be useful to other leaves. The intercellular spaces of the spongy parenchyma receive and distribute to all parts of the leaf the carbon dioxide that has entered through the lower surface. The border parenchyma or collecting cells (Diagram III), which border the veins, deliver water from them to the rest of the mesophyll and receive food from

palisade and spongy cells and, together with the phloem elements of the veins, serve to transport it out of the leaf.

Respiration and Liberation of Energy

In green plants all the organic substance produced by carbon assimilation is not used for purposes of construction and storage; a part of it is always broken down and returned to the state of inorganic compounds. This process is, in all respects, exactly similar to that taking place in the animal organisation during breathing, i.e. the intake of oxygen and expiration of carbon dioxide during respiration. The significance of the process does not lie in the substances formed but in the liberation of energy which is essential for the life of the plant. By respiration, in its typical form, is understood the oxidation of organic material to carbon dioxide and water; this involves the absorption of oxygen from without.

Though respiration goes on in every living cell, its intensity varies greatly in different organs and under various external conditions. Actively growing parts exhibit very active respiration. Among external conditions which have an important influence on the intensity of respiration, the temperature and the amount of oxygen must be specially mentioned. An increase in temperature accelerates respiration as it does all the vital processes. With continued rise of temperature, however, the respiration diminishes.

At first sight respiration appears a contradictory process to carbon assimilation, since during the process organic material, which has been built up in assimilation, is again broken down. Its meaning only becomes evident when, turning from the aspect of changes of substances, that of energy is considered. It is not the production of carbon dioxide and water which is important, but the liberation of energy. This is effected on the breaking-down of such substances as carbohydrates, for the construction of which, as has been seen, a supply of energy is requisite. On this liberated energy, the plant is dependent for the driving force in many of its vital phenomena. Movements of protoplasm, growth and movements due to stimuli cease on the withdrawal of oxygen from the plant. All these vital phenomena begin again on the restoration of a supply of oxygen, if this has not been too long delayed. It might have been expected that the organisms would possess arrangements by the help of which the external energy of light and heat could be employed as driving power. Practically, however, it is found that the plant proceeds to store up the energy of the sun's rays in the form of potential chemical energy,

e.g. building up of carbohydrates, and then utilises this at need. This method has the great advantage that the stored energy can be very easily carried to other places in the plant. It can thus reach, for example, the roots which grow in the dark and cannot directly transform light into chemical energy. Further, the stored energy can be employed at a time when the sun's energy is not available, e.g. at night.

Thus, a green plant stores energy by the construction of organic substances such as carbohydrates formed during assimilation, but at the same time organic substances are lost during respiration in order to liberate energy which enables the vital processes to function normally. *Assimilation and respiration are two distinct vital processes carried on independently by plants. While in the process of assimilation green plants alone, and only in the light, decompose carbonic acid and give off oxygen, all plant organs without exception, both by day and by night, take up oxygen and give off carbonic acid.* This view, first formulated by the famous botanist Sachs, forms the basis of all physiological experimental work in plants. *En passant*, non-technical readers should regard carbonic acid and carbon dioxide as equivalent terms.

At the present stage, an outline only, and that of the barest possible kind, has been given of the important conducting conduits, and the movements of nutrient solutions and elaborated food materials along them. The movements of food materials from one part of a plant to another are naturally governed by the vital processes, to which some attention has been given. In healthy plants, the formation and transport of food materials can only take place in a normal way if the vital processes are working in a balanced state; any external factors which may have an overwhelming, depressing influence on one particular process will upset the natural balance, and from this point of view, health in plants may be regarded as a state in which each organ performs its own function efficiently and in harmony with all others. Disease, in the broadest sense of the word, consists of any departure from that state. A condition of disease proceeds from a derangement of any physiological function, and in plants this most frequently follows upon derangement in structure.

PART III

DISEASES AND PESTS

SECTION I

ROOT DISEASES

CHAPTER VII

GENERAL

Systematic Position of the Fungi causing Root Diseases—Wounding during Cultivation Operations in Young Rubber—Trenching, including Silt Pitting on Hilly Estates—Low Cover Crops and Bushy Cover Crops susceptible to Fungus Attacks, more especially *F. lignosus*—Liming, with special reference to *F. lignosus*—Tree Surgery, with special reference to *U. zonata*—Root Diseases and White Ant Attacks—Yields from Trees attacked by Root Disease.

SYSTEMATIC POSITION OF THE FUNGI CAUSING ROOT DISEASES OF HEVEA BRASILIENSIS

FOR many years the exact systematic position of the fungi causing root diseases of rubber trees has been very obscure. Recent work by Corner has thrown much light on some points. In the writer's opinion, the name attached to a fungus causing a root disease of rubber trees is of little interest to the planter, for he considers the name merely as a handle, which is convenient to use when the subject happens to be under discussion. To the best of the writer's knowledge Table I is correct, giving the taxonomic position of the fungi causing diseases of roots of rubber trees, with their synonyms.

A few remarks may help readers to understand the present taxonomic position more clearly. The fungus causing white-root disease was originally recorded as *Fomes semitostus* by observers in the rubber-growing countries of the Middle East, and before 1914 most of the literature dealing with this disease referred to the fungus by this name. It was then discovered that the original *F. semitostus* is quite a different fungus. The above information is taken from Petch's 1921 edition, and he adds that "the correct name of the species which causes this rubber root disease is *Fomes lignosus*". About 1914 Petch began to use the name *Fomes lignosus*, Klotzsch, and it is by this name

that it is now well known to the planting community. In 1923 Van Overeem declared that *F. lignosus*, as we know it, was only one form of a very variable fungus of world-wide distribution, and that over thirty varieties of the same fungus had received different names from different investigators; in other words, he claimed that the fungus had over thirty synonyms and had not up to that time been correctly named. He therefore proposed the name *Rigidoporus microporus*, Swartz. Van O. This proposal did not simplify the situation and the

TABLE I

Common Name	Present Name	Synonyms
White-Root disease	*Fomes lignosus*, Klotzsch	*Fomes semitostus*, Berk. *Rigidoporus microporus*, Swartz. Van O. *Polyporus zonalis*, Berk. and according to Van Overeem, thirty-three other names.
Red-Root disease	*Ganoderma pseudoferreum* (Wakef.), V. O. et St.	*Fomes pseudoferreus*, Wakef. *Poria hypolateritia*, Berk. *Poria hypobrunnea*, Petch *Trametes theae*, Zimm.
Brown-Root disease	*Fomes noxius*, Corn.	*Hymenochaetae noxia*, Berk. *Fomes lamaoensis*, Murr.
Dry Rot disease	*Ustulina deusta*, Petrak	*Ustulina zonata* (Lev.), Sacc. *Ustulina maxima* (Web.), von Wettstein
Stinking Rot disease of roots	*Sphaerostilbe repens*, B. & Br.	

problem demanded attention from other authorities. Petch did not agree with Van Overeem's conclusion, and he made a statement, in 1928, that the fungus known to the rubber planter as *F. lignosus* is, as yet, an unnamed species. He remarks, "I am unable to visit Berlin and check this suggestion by inspection of Klotzsch's type specimen". Later, Weir stated that he has in his own herbarium a portion of the original specimen named by Klotzsch, and that in his opinion the name *Fomes lignosus*, Klotzsch, must stand. The writer is prepared to accept Weir's finding.

The position is clearer with regard to *Ganoderma pseudoferreum*

(Wakef.), V. O. et St. When the disease was first reported in Malaya, only young and immature specimens of fructifications could be found. For purposes of convenience a name had to be found for the fungus, and this could only be done by consulting various works of reference dealing with tropical crops. The general symptoms appeared to correspond more closely to those described for the disease on Tea bushes known as red-root disease, ascribed to *Poria hypolateritia*, Berk., than to any other known root diease. The disease thus became known in Malaya as *Poria* disease and is still referred to in this way. At a later date specimens of the immature fructifications were forwarded to Kew for examination by Miss E. M. Wakefield, who, although she was averse to supplying a name from such poor material, finally acceded to our continued requests and provisionally named the fungus *Fomes pseudoferreus*. This was an excellent determination for such unpromising material, although, later, Van Overeem transferred the fungus to the *Ganoderma* section of the *Fomes* group as *G. pseudoferreum*, and to-day planters commonly speak of the *Ganoderma* disease.

With regard to brown-root disease caused by *Fomes noxius*, Corner has published the latest information obtained during his recent researches. Up till about 1920 the disease was commonly spoken of as the *Hymenochaetae* disease because the causal fungus was considered to be *Hymenochaetae noxia*, Berk. In 1917, Petch found fructifications on jungle stumps, Tea and *Hevea* killed by brown-root disease, which he sent to Lloyd for identification, and this systematic worker identified the fungus as *Fomes lamaoensis*, Murr. After the most careful consideration Corner suggests that some confusion had arisen, and points out that two similar, but different, fungi have both been included under the same name, which properly spelt, should be *Fomes lamaensis* (Murr.), Sacc. et Trott., and not *Fomes lamaoensis*, Murr. The fungus which is rightly named *F. lamaensis* is a harmless saprophyte; the other is a facultative parasite and is the true cause of brown-root disease of *Hevea brasiliensis*. This latter fungus is designated by Corner as *Fomes noxius*, n.s.

For the disease known as "Dry-Rot", the common name used for the causal fungus by planters, even at the present date, is *Ustulina zonata*. In 1924 Van Overeem brought forward strong evidence to show that *Ustulina vulgaris*, Tul., and *Ustulina zonata* (Lev.), Sacc., which hitherto had been considered to be two distinct species, were one and the same fungus. *Ustulina vulgaris* is known to occur all over the world and is a genuine cosmopolitan fungus, while *U. zonata* is only known to occur in tropical Asia (India, Ceylon, Malay Archi-

pelago). He suggests that these fungi should be referred to one species, to be known as *Ustulina maxima* (Web.), Von Wett. Petch agrees that *U. vulgaris* and *U. zonata* are identical with each other, but points out that the name *Ustulina deusta* was suggested for the combination by Petrak, in 1921; therefore the name should be *Ustulina deusta*, Petrak. This may be correct from the systematic point of view, but as the name of *U. zonata* is so well established among laymen, the writer feels there is sufficient justification for its continued use.

Referring to *G. pseudoferreum*, Corner remarks that this species comes very close to *Ganoderma applanatum* (Pers.), Pat., of which it may prove a variety. This is a very widespread and variable species. Further, Petch has shown that Van Overeem's citation of *Poria hypobrunnea*, Petch, *Poria hypolateritia*, Berk., and *Trametes theae*, Zimm., as synonyms for *G. pseudoferreum*, is false.

The only fungus causing a root disease on rubber trees which has escaped adventures at the hands of the systematists is *Sphaerostilbe repens*, B. & Br.

When comparing the above list with that given by Petch in 1921, it will be noted that he records red-root disease on rubber trees as being caused by *Poria hypobrunnea*, Petch. This record has never been made in Malaya and it is apt to lead to some confusion in this country, since the disease caused by *G. pseudoferreum* is now commonly referred to as red-root disease. It can be taken for granted, however, that *G. pseudoferreum* is the true and only cause of the typical red-root disease of *H. brasiliensis* found in Malaya.

For various reasons, the writer is not following the same order of presentation of the individual root diseases as that adopted by Petch and Steinmann. It is most important that white-root, red-root and brown-root diseases should be treated as a closely connected group rather than to consider them as individual diseases of the type represented by *Ustulina zonata* and *Sphaerostilbe repens*. The earlier description of these two individual diseases will also make for better continuity. To avoid misunderstanding, it should be understood that the above remarks apply more especially to Malaya and not to Ceylon, for in the absence of *G. pseudoferreum* from that country, it is difficult to gauge accurately the true position.

The question of descriptive names such as white-root, red-root and brown-root diseases, has often been commented upon, usually adversely. While admitting the possibility of confusion arising, a forcible presentation to the layman of the main diagnostic symptoms of a particular disease, more especially if they are easily discernible, is

surely of the greatest value. It has been stated that wet-root rot is a misleading name for the disease caused by *G. pseudoferreum*, because *F. lignosus* may also on occasions cause a wet-rot in rubber roots. But the disease-situation in a permanent crop, during any particular period, may change as the seasons of the year show varying climatic conditions. The writer differs from other workers, who consider the term wet-root rot an unsuitable one. In the year 1916 a more suitable common name for the disease caused by *Ganoderma pseudoferreum*, as seen then only on trees approaching ten years of age, could not have been chosen. It is only recently, in 1931, since the discovery of young trees attacked by *G. pseudoferreum*, that any definite reason for a change could be advanced. Steinmann remarks that the name wet-root rot was an injudicious choice for the *G. pseudoferreum* disease, but the argument can be advanced that it would be extremely useful to planters to know that, in the majority of cases, trees approaching ten years or over, which show a wet-rot disintegration of the root tissues, are attacked by *G. pseudoferreum*. As Petch, however, has attached the descriptive term of red-root disease to an affection caused by an entirely different fungus, it seems that confusion would be apt to arise whatever choice is made. But there is reason for changing the descriptive name in Malaya, from wet-root rot to red-root rot, because white-root rot and brown-root rot are names definitely established there and the change of name emphasises the close relationship of the three diseases, all caused by fungi of the *Fomes* type.

When dealing with the general question of root disease on rubber plantations, there are several minor, though none the less practical, issues which have to be considered in relation to the main problems. Questions are often asked such as whether a thick growth of a cover crop in the early stages of a plantation will influence the spread of *F. lignosus*; and whether the cultivation operations such as weeding and forking, turning in of cover, etc., which might have to be undertaken to keep the cover in order, will result in extra wounding, thus giving the fungus an easier method of entry into the roots? Indirect factors such as these, which have been considered to influence the spread and control of the various root diseases, may be profitably dealt with at this point. If this is done, readers will be aware what to expect when the individual diseases are dealt with in detail.

The following items call for mention:

(*a*) Wounding during cultivation operations in young rubber.
(*b*) Trenching. Also silt pitting, more especially on hilly land.

(*c*) Low cover crops and bushy cover crops susceptible to attacks by fungi causing root diseases on rubber trees, more especially *F. lignosus.*

(*d*) Liming, with special reference to *F. lignosus*, but also to all root diseases of rubber trees in Malaya.

(*e*) Tree surgery, with special reference to treatment of old mature trees which have been badly diseased by *U. zonata* for a considerable time.

(*f*) Root diseases and white-ant attacks.

(*g*) Yields from trees attacked by root disease.

Before taking up these issues individually, some remarks on the type of root system developed in Malayan soils by *Hevea brasiliensis* would be to the point. In suitable soils with a deep water-level, the tree produces a long tap-root which grows straight downwards through the soil to a depth of several feet. In low-lying ground, where the water-level is not more than two feet deep, as in practically all the coastal areas where rubber has been planted in Malaya, the tap-root does not grow below the water-level and a squat, rather rounded, terminal protuberance is formed. In such cases it is not difficult to understand that the lateral root system will be wholly confined to the upper two feet of soil. But even in areas of good soil, where the tap-root may grow to a depth of many feet, the majority of the large lateral roots, comprising most of the root system, are also found in the upper two feet of soil. This is of considerable importance in the treatment of root diseases; since, if treatment, for instance, by chemicals or manures is indicated, they can be applied with some assurance that they will reach the place intended. Trenches can also be dug with confidence, so that they will efficiently separate diseased from healthy trees.

Since new areas have been opened up in the last few years for the purpose of developing high-yielding strains of rubber trees, the practice of planting cover crops to prevent soil erosion and to provide soil shade, has been more carefully followed than in the past, during which period a policy of clean weeding has been very popular. There is no doubt that the young rubber plants are given better conditions of growth generally when a cover crop is grown successfully, but there is a certain disadvantage to be noted. The cover plants enter into competition for food with the young rubber plants, and the latter undoubtedly suffer retardation in growth as judged by the recorded increase in girth. This defect might be removed if the cover plants were turned in and incorporated in the soil. This operation is seldom carried out in Malaya, for it is expensive, and it is generally held that

in view of the excessive rate of decomposition of green matter in tropical soils, there is but slight formation of humus and it is doubtful if much would be gained by this form of cultivation. The present practice in Malaya is merely to "ring weed" and keep the soil clear round each tree, in a circle of about 2–3 feet radius. A leguminous, low-growing cover plant is usually planted in Malaya. Bushy covers have never found favour as they have in Ceylon, where they are very popular, more especially in cultivations other than rubber. The book which should be consulted by planters for information on low or bushy ground covers is *A Manual of Green Manuring* (Dept. of Agriculture, Ceylon, 1931).

It has been the practice in former years, and will probably continue to be so, to set more plants per acre than is actually necessary and, at a later date, any superabundance can be removed. Mention of this will be made later. This procedure is undertaken chiefly to prevent too large a loss of stand from disease attacks. It is between the planting and thinning-out periods that cultivation methods of various kinds have been put into operation, and it is quite possible that a significant amount of wounding has been done to the collar and root systems by the implements used. The writer believes that such injuries can be ignored in connection with diseases in rubber trees growing in suitable situations. It must be mentioned, however, that the fact of *Ustulina zonata* functioning as a wound parasite has been fully established.

Readers will realise that in a book fundamentally devoted to diseases of the rubber tree, side issues such as establishing cover crops, cultivation operations, silt pitting, etc., can only be treated in a somewhat cursory manner, as limitations of space prevent a comprehensive treatment. Only brief mention will therefore be made of the actual methods used and the objects which planters have in view. The items enumerated above will now be dealt with in their direct relationship to spread and control of root diseases of rubber trees.

Wounding in Young Rubber during Cultivation Operations

Previous investigators have generally been inclined to believe that any wounds made on the young roots, or in the vicinity of the collar, would adversely affect the trees, in that they would become more prone to root diseases, presumably because they would be much more easily attacked by the various fungi concerned. Apart from the fact that *H. brasiliensis* possesses an exceedingly efficient repair mechan-

ism, which has been but recently recognised by the researches of the writer and Gunnery, it is now the firm opinion that the *Fomes* group of diseases are not favoured in the slightest degree by wounding of the roots or collar, for these fungi make a direct entry into roots without extraneous aid. Root-wounding can therefore be largely discounted as a source of trouble in the most important root diseases.

Only two root diseases now remain to be considered in this connection: those caused by *Sphaerostilbe repens* and *Ustulina zonata*. We have very little definite knowledge concerning the factors which influence the fungus in its entry into the plant in the case of *S. repens*, and the root disease caused by this fungus can be thus dismissed. This leaves but one disease (*U. zonata*) of importance for consideration, and in this also there is still much to be learned. This fungus is a wound parasite, not only in roots, but also in stems and branches. Collar infections, however, are the commonest type of the disease, but in these cases wounds made during cultivation operations with cover crops in the early stages of the plantations can have but little influence. The main factor influencing the increase in number of cases of collar disease caused by *U. zonata* is stated later when dealing with the fungus in detail.

TRENCHING: ALSO SILT PITTING ON HILLY LAND

Trenching has been generally recommended for treatment of root diseases on rubber plantations, and they were supposed to be pre-eminently useful in the control of *Fomes lignosus* in young rubber. Trenches for isolating disease patches are usually recommended to be dug two feet deep, and not less than nine inches wide. The type of soil may cause some modification of these figures, but the depth is the important unit, and this should not be less than two feet.

Napper has recently shown clearly that isolation trenches are quite useless in the control of attacks of *Fomes lignosus* in areas of young rubber in Malaya. In fact, there is no reason at all for trenching for this disease, if a systematic root-disease inspection is periodically carried out, as will be explained later.

A system of trenching can be recommended for treatment of areas affected by *Ganoderma pseudoferreum* when the diseased rubber trees are from ten to twenty years of age. The usual geometrical form of trenching will have to be abandoned, for the position of diseased groups of trees will, as detailed later, determine the size and configuration of the trenches. In the case of other root diseases, the most

important matter is to get the soil free from all diseased material, and in order to accomplish this, a trench which includes the whole of the diseased area may prove to be of some utility.

Silt pitting may be dealt with here. Silt pits are discontinuous trenches, made much wider than the ordinary trenches dug during disease control work. They are dug about 2 feet deep, 2 feet 6 inches wide, and are made usually about 6 to 8 feet long, running along the contours of hilly land. They are placed in a suitable position so that all the suspended soil which is washed downwards during storms is caught, and loss of the important top soil is thus prevented to a large extent. Silt pits are made much wider than disease trenches so that soil erosion can be prevented successfully.

When a system of silt pits is installed in mature rubber there is often a marked increase in the number of cases of *Ustulina zonata*, owing to the cutting of large lateral roots, which are left untreated or treated carelessly. All roots cut during silt pitting operations should have their ends trimmed straight, and the exposed tissues should then be dressed by a reliable wound cover. This will prevent any spread and increase in number of cases of *U. zonata*.

In addition to their useful function on hill land, silt pits help to improve soil aeration in most types of Malayan soils. On hilly land, the capacity of the silt pits should be sufficient to retain the heaviest rainfall during any period. One of the most important features in mature rubber, where attention has been definitely given to keeping the silt pits in good condition, is the possibility of utilising these in a trenching scheme when trees attacked by *Ganoderma pseudoferreum* are found. Of course, expert advice would have to be sought, but the method has been tried out successfully.

Low Cover Crops and Bushy Cover Crops, susceptible to Attacks by Fungi causing Root Diseases on Rubber Trees, more especially F. lignosus

In a later section, considerable attention is given to the desirability of maintaining soil conditions in a state suitable for the growth and development of the rubber tree to full maturity, i.e. to as great an age as possible. It must be admitted that soil shading and prevention of soil erosion is eminently desirable if the natural life of a rubber tree is to be prolonged to obtain the fullest economic utility. In Malaya these desiderata are usually provided in young areas by establishing a light-loving, low-growing, leguminous cover crop. As the rubber tree grows to maturity, more and more shade is thrown

on the ground, so that the light-loving, low cover naturally disappears, for the intensity of the light is decreased enormously under normally developed, mature rubber trees, as compared with the amount of light available for cover crops in the first to the fourth years. Concurrently, soil shade is provided which will keep the soil at a normal temperature.

But, under the circumstances, there seems to be no adequate provision for preventing soil erosion, and as the trees make more demands on the soil as they grow larger, every possible advantage should be taken of increasing the humus content of the soil, so as to make it a more suitable medium for plants which are possibly exacting in so far that they may require large amounts of food material. Shade prevents the adoption of the methods used in the early stages when plenty of light is available, and only shade-loving plants can be utilised as a cover crop under mature trees. Up to date, only shade plants growing under natural conditions have been found suitable, and those which maintain a succulent habit, without becoming definitely woody, are chosen for development and multiplication. The development of natural growths as cover plants under mature rubber has led to the exploitation of similar ideas in young rubber areas, and cover crops, consisting of plants which appear naturally, have been successfully established in a few areas in Malaya.

It can be stated at once that some low-lying and bushy leguminous covers are subject to attacks by *Fomes lignosus* (Fig. 7).

Details need not be given here, and it will be sufficient to remark that the conditions under which cover crops might be *expected* to promote root disease are found on areas where *Fomes lignosus* is abundant, and then only when the cover, natural or leguminous, develops into a thick, impenetrable mat. The word in italics should be noted especially, for Napper, as a result of his recent researches, says: "It is probable that the disease [on rubber trees] in a young clearing is less under a cover crop than in clean weeded areas". This statement can be taken to apply generally, for wherever cover crops, of whatever type, susceptible to *F. lignosus* are established, they exert a kind of "baffle" action and retard the rapidity of spread of the fungus amongst the rubber trees, although the actual amount of viable mycelium may possibly be considerably greater. So it appears that while a knowledge of this effect may be useful in so far that attention to the activities of the fungus might be deferred as long as the rubber trees themselves are not affected, yet if the fungus appears on the roots of the rubber trees more time and trouble must be spent finally. During a period when money is difficult, any policy

which defers expenditure is helpful, but not always to the ultimate advantage of the people interested.

The question of root diseases in mature areas under a thick natural cover brings up again the subject of the latter exerting a "baffle" action and retarding the spread of the more important root diseases, more especially that caused by *Ganoderma pseudoferreum*. This question is a recent development and some comment is necessary since claims have been made that immune strains of rubber trees may be

FIG. 7.—Showing rhizomorphs of *F. lignosus* growing and ramifying amongst leaves and debris in the plantation.

developed if they are grown for a sufficiently long period on soil areas permeated with *G. pseudoferreum*. It may be said at once that there is no evidence to indicate the possibility of immune strains of *H. brasiliensis* developing under any set of growth conditions. It seems more probable at the present time that favourable conditions for rubber trees are just as likely favourably to affect the various disease-causing fungi. There is one case known where, if there is not careful supervision, a fungus disease will definitely act as a limiting factor on mature rubber growing under the more favourable conditions presumably provided by a dense natural cover.

Application of Lime, with special reference to Control of F. lignosus

It is commonly held amongst a large number of planters that liming should be undertaken for the purpose of controlling outbreaks of root disease. Petch, in his 1921 edition, recommended the use of lime, because the majority of fungi prefer an acid medium. It was therefore held that by rendering a soil more alkaline, the fungi causing root diseases on rubber trees would suffer a definite check. Bryce, in 1922, showed that this view could not be supported in the case of *Fomes lignosus* in Ceylon, and work carried out in Malaya has confirmed his conclusion. Nothing will be gained by liming the soil on diseased areas, but there may be special circumstances in which lime may be used profitably, as in badly drained areas where the trees are sickly and offer little resistance to the heavy attacks which often develop in such localities, in spite of the depressing effect on the fungus of the sourness of the soil. Under these conditions it is probable that the beneficial effect of liming (combined with adequate draining) upon the growth of the host plants, will outweigh any detrimental effect which may follow the concurrent increase in the activity of the parasite in the soil. For these reasons it is suggested that the application of lime to the soil may be of utility when dealing with localised areas, which have carried trees suffering from the diseases caused by *Sphaerostilbe repens* and *Ustulina zonata* for a considerable length of time. The above must not be considered a general recommendation, but if advice can be obtained on the point, it is worth while enquiring whether lime would or would not be beneficial.

Tree Surgery, with special reference to the Treatment of Old Mature Trees which have become badly diseased at the Collar by Attacks of Ustulina zonata

This subject has received more attention in Ceylon than in Malaya. The writer's views will be given when the control of the fungus is being discussed. In Malayan rubber plantations, tree surgery methods could not be adopted with any degree of success except for filling large holes caused by breaking of large branches, which afterwards become infected by *U. zonata*, or for filling cavities caused by hacking away diseased tissue at the collar, caused by *U. zonata*. From an economic point of view there seems little to recommend the adoption of tree surgery in Malaya, but some readers may be interested, so a short extract from Petch is given:

The idea of filling tree cavities is not a new one, but it is only comparatively recently that methods have been adopted which are likely to prove successful. Stopping tree cavities is analogous to dentistry, and two cardinal principles must be observed, viz. all decayed tissue must be cut away, and the filling must completely fill the hole, so that water cannot lodge behind it or fungus spores and insects obtain an entrance.

It is doubtful whether this method can be advantageously applied, in the case of *Hevea*, to large cavities in the upper parts of the tree. The wood of *Hevea* is brittle, and the excision of all the decayed tissue would probably weaken the stem to such an extent that it would break off. On the other hand, if such cavities are not treated, the stem will ultimately break off owing to the progress of the decay. In this respect prevention is better than cure; and more attention should be given to correct pruning and periodic tarring of wounds.

Cavities at the base of the tree, however, could safely be treated. All the diseased wood must be cut out (this is easier said than accomplished); otherwise the fungi will continue to destroy the wood behind the filling. Successful treatment depends chiefly on the thoroughness with which the diseased wood is removed. It should then be painted with a coat of white lead paint and afterwards be filled solid. Creosote or Brunolinum, etc., followed by a coat of tar may be used instead of white lead paint. (In Malaya, a solution of Solignum has proved to be one of the most useful wound covers for this purpose.)

Various mixtures are used for the filling. Bricks, stones, and cement is the most usual, the cement being mixed with two parts of fine sand. There should be no spaces left between the filling and the wood, and the outer face of the filling must be finished off smooth with the cement. The bricks and stones merely add bulk to the material; the lining next the wood should be cement, and the bricks, stones, etc. embedded in the middle of the cavity. After the filling has set it is left for a day or two, and then covered with coal tar to prevent cracking. The filling must not be brought level with the outer bark of the tree. What is desired is that the callus from the edges of the wound should grow over the cement, and either cover it completely or at least cover it at the edges so that it holds it in position. Hence the filling should only be brought to the level of the cambium.

In the case of cavities in branches in which rain water collects, care must be taken to see that they are quite dry before filling is attempted. If they are very deep, an auger hole should be bored into the branch to reach the base of the cavity so that any water will drain out.

On branches which are liable to bend and sway in the wind, a cement filling may crack and fall out. In such situations a mixture of asphalt and sawdust is used, in the proportion of one part of asphalt to four parts of dry sawdust. The sawdust should be from hard wood. The mixture is prepared by stirring the sawdust into boiling asphalt, and it is applied before it has cooled.

The writer has little confidence in the suggested methods for use on Malayan plantations. There are great practical difficulties attend-

ant upon clearing away all the diseased tissue, and this is sufficient to make anyone, well acquainted with the conditions, hesitate before recommending such a course of treatment.

If further details are required, the report by Stoughton-Harris, which is given in the table of literature, should be consulted.

Root Disease caused by Fungi and White Ant Attacks

This will be dealt with under the section dealing with white ant attacks, but a brief reference may be made here. Most entomological workers have referred to the subject and their opinion has usually been that white ants never or very rarely attacked a healthy rubber tree. There was general agreement that they were often found associated with the root diseases caused by *Fomes lignosus* and *Ustulina zonata*, but it was usually held that the fungus had made the prior attack. During the last two years, researches in Malaya have proved undoubtedly that these insects will attack a healthy, unwounded rubber tree, and will kill it in a very short space of time. There is therefore no reason for any further misconception on this point.

Yields from Trees attacked by Root Disease

Petch states that the effect of root disease on the yield of latex (in Ceylon) is highly variable. In Malaya, the general opinion is that trees suffering from root disease are usually, until a large proportion of the root system is definitely put out of action by the parasite, exceptionally good yielding trees. It is a common saying that all the trees which have been in tapping for any length of time and which happen to be the ones first found suffering from an attack of red-root disease, are the good yielding trees. There is a very good reason why this should be so, as will be explained later.

The position in respect of other root diseases is not so clear. *Fomes lignosus* can be ruled out of court in Malaya because the main attack should be under control, if not wholly wiped out, before the trees are opened up for tapping. *Fomes noxius* is of small account, but attacks of *Ustulina zonata* and *Sphaernostilbe repens* are often found on trees yielding well above the average. The writer has vivid recollections of one of the first fields of eighteen-years-old rubber, which was giving the high yield of nearly 1000 lbs. per acre per annum, and had done so over a period of five years. About 1916–17, *S. repens* became very prominent in this field and, in conjunction with a boring beetle attack, practically wiped out every tree.

The various sections following and included under Root Diseases will be self-explanatory and will not present any complications, excepting the concluding one. This section is devoted to the question of replacing areas of mature rubber, which have become uneconomic units at the present date. The question has become prominent, since it has been largely accepted that greatly increased yields may be obtained from old rubber areas if good, cultivable soil is planted up with good stocks of rubber plants, on to which individuals of those clones which have been proved to possess all the desirable qualities are bud-grafted. The common terms used for replacement of old areas are rejuvenation and replanting. This subject has been dealt with by Taylor, in so far as it is a problem facing rubber plantations in Ceylon. As the section on root diseases is studied by readers, it will become increasingly evident that there are many features in Ceylon and Malaya which are essentially different. In Malaya, this particular problem arises fundamentally from the fact that groups of trees become diseased by root contact when they have reached fifteen to twenty years of age, and replacement in such areas can be done only by undertaking replanting. In Ceylon, Taylor draws attention to the possibility of rejuvenating areas of old rubber trees by allowing good yielding trees to remain *in situ* while tapping is continued on these trees. Poor yielding trees in these areas, giving below 10 lbs. per tree per annum, which amount is considered to be the economic yield, should be replaced by bud-grafted individuals, which have been proved capable of yielding 10 lbs. per tree in their first year of tapping. Taylor's views for Ceylon focus the problem largely as an agricultural one, and perhaps for this reason the subject should not be included in a section devoted to root diseases. But the writer feels impelled to include the subject in this section rather than to defer it to a later stage, because in Malaya the question is so absolutely dependent on the root disease problem, more particularly in connection with the disease caused by *Ganoderma pseudoferreum*, a disease which has not yet been reported from Ceylon. The position in Java is similar to that in Malaya.

CHAPTER VIII

USTULINA ZONATA—SPHAEROSTILBE REPENS

USTULINA ZONATA, LEV. SACC.

IN Malaya the disease caused by this fungus is found on old rubber areas in every part of the peninsula. It has been recorded attacking *Hevea* in Java, Fiji and Ceylon. In the latter country, it has been known for many years as the cause of the commonest root disease on Tea.

The disease has not shown up prominently on young trees, though occasional attacks on trees not more than two to three years of age have been recorded. It is seen in its several forms in mature areas over twenty years of age, but is commonly found in trees not more than ten years old. This fungus, in conjunction with *Ganoderma pseudoferreum*, has been the main factor in destroying the economic efficiency of the older stands of rubber, but in this respect *G. pseudoferreum* stands pre-eminent.

The disease is usually discovered on old trees as a "collar rot". On one side of the stem a hollow at the base may be formed due to the rotting tissue disintegrating under the influence of the weather and falling away. If a cut is made below the surface at such a point, it will be found that the rotting tissue has spread to a distance of three to four feet above ground-level. It is seldom that the fungus gains a greater height than this, for by this time most of the tissues at the base of the stem will have become involved, with a consequent restriction in the amount of water supplied from the roots. One case examined in 1916 showed the fungus travelling from the collar up through the heartwood of the stem into the lower branches, some twelve feet high. This infection might have been a double one: (*a*) a branch infection travelling down the stem, and (*b*) a collar infection travelling upwards, with the two infections eventually joining up. If an attacked root system is examined, it will be found that the tap-root and some of the larger laterals are involved, and as a result water conduction will be stopped along these roots and the crown of the tree must suffer, gradually going out of commission.

The characteristic symptom of the disease is the "Dry-Rot" set up in the attacked tissues. In some cases, conspicuous black lines can

be seen on the outer surface of the wood; if the lines are followed carefully, it will be found that they form thin black plates running through the internal tissues of the woody stem, their edges showing as black lines on the exterior (Fig. 8). A longitudinal section taken through the collar of a diseased tree shows these black lines running irregularly in the rotting tissues, often forming circles surrounding dark-coloured patches of diseased wood. The black lines are composed of aggregated fungus tissue, formed by the massing of hyaline hyphae; this massing always commences in the medullary ray cells. Tracts of connecting cells between the rays later become filled with similar tissue and a continuous line is formed. What appears to be carbonaceous material is deposited in the infested cells after the aggregation therein of the fungus hyphae, and as time passes it is difficult to detect the exact origin of the lines. The cells bordering the black lines are crowded with hyaline hyphae.

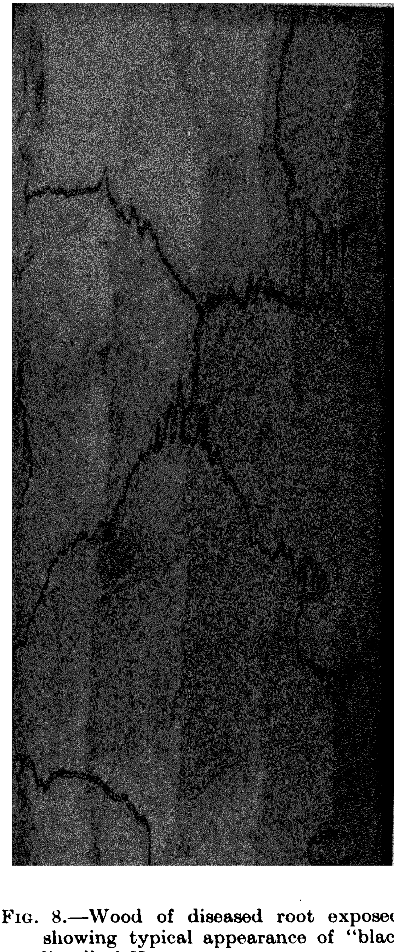


FIG. 8.—Wood of diseased root exposed, showing typical appearance of "black lines" of *U. zonata*.

Such aggregations of fungus hyphae might be considered rhizomorphs, but as they are strictly confined to the diseased tissue they have not the power of growing freely along the exterior of the root and so cannot effectively function as organs for vegetative spread in area. But they retain their vitality for considerable periods and if portions of diseased wood, containing black lines, become scattered about in the soil, there is a definite chance that roots of healthy trees, which come into

contact with such infective material, will contract the disease.

There is no external mycelium associated with roots suffering from this disease, though fan-shaped, white patches of a felt-like mycelium may be sometimes observed on the exterior of the wood, when the bark is removed.

It should be noted that other fungi, more or less closely related to *U. zonata*, also produce similar black lines in dead and decaying wood found lying about the plantations. Thus in diseased rubber trees, reliance can only be placed on the black lines as a diagnostic character,

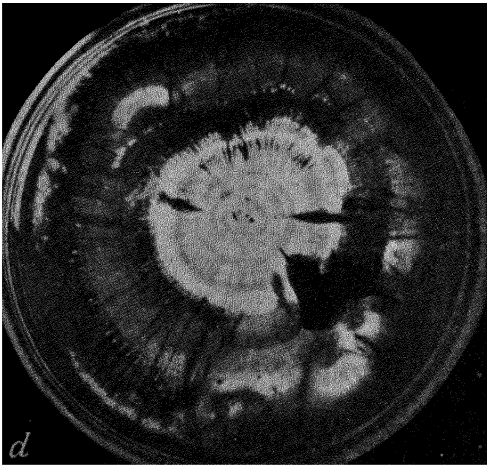


FIG. 9 *d*.—Incipient white tipped aggregations of mycelial hyphae (Rhizomorphs?), of *U. zonata* developed in plate cultures. (From *Anns. of App. Biol.*)

when the trees show the typical dry-rot in the woody tissues, either in the root or stem system.

The possible relation between the aggregations of fungus tissue, which form the black lines, and rhizomorphs, is referred to above, and also in Part I. The mycelial aggregations in the form of minute strands of fungus tissue which are developed in pure cultures, is shown in Fig. 9 *d*. These are very similar to the strands developed in pure cultures of *Sphaerostilbe repens*, and it is now realised that this fungus freely produces microscopical rhizomorphs, of typical form, in invaded cortical tissues of rubber roots.

The progress of the disease is slow, after infection has taken place. This is connected with the fact that the water-conducting vessels are comparatively little affected by the activities of the fungus developing

in the attacked tissues. During its progress through the woody tissues, the fungus is largely confined to the medullary ray cells and the fibres of the wood. Quick travelling fungi use the long, tubular vessels of the wood as their route for moving from one part of the plant to another, for there are no cross walls to intercept their progress. The death of large, heavily infected trees may be delayed for many years, and if the yields of latex do not fall to any great extent, there is no real reason why such trees should be taken out of the tapping round. Finally, however, trees attacked by *U. zonata* disappear from the tapping round, either because the yield of latex becomes too small for their profitable retention, or they are blown

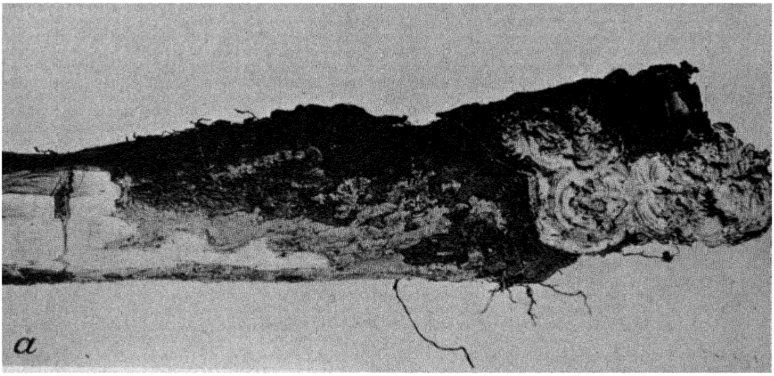


FIG. 9 *a*.—Fructification of *U. zonata* developed on diseased rubber root. Note typical zonation.

down during the heavy wind and rain storms which occur so commonly in Malaya during certain periods of the year.

Fructifications.—The fructifications are often produced in profusion at the base of the stem, before the death of the tree (Figs. 9 *a* and *c*). The young fruit body commences as a small, yellowish-white plate closely addressed to the bark. It emerges through the bark as a short, white column and spreads out in all directions flat on the surface, being attached to the bark only at the point of origin. The plate increases in size and the surface darkens to a greenish-grey colour, owing to the formation of a thick layer of conidial spores. These are borne on erect stalks which are closely compacted to form a continuous surface (Diagram IV, 1).

As the spores are borne superficially they are easily blown away by wind, and insects walking over the flat plate would probably transport

the spores on their appendages. This phase may continue for about one week, and during this period the plate is soft and easily cut. As the conidial layer disappears, the flat fructification becomes darker in colour; gradually it becomes more leathery in consistency and ultimately becomes brittle and quite black. Typical young specimens gathered outside in the field show a well-defined zoning on the surface, hence the name of *U. zonata* (Figs. 9 *a* and *c*). When fully developed, the plate-like fructifications are several inches in diameter. A number of plates may fuse together, until several feet of the diseased stem may be covered with the fructifications. When the plates are black

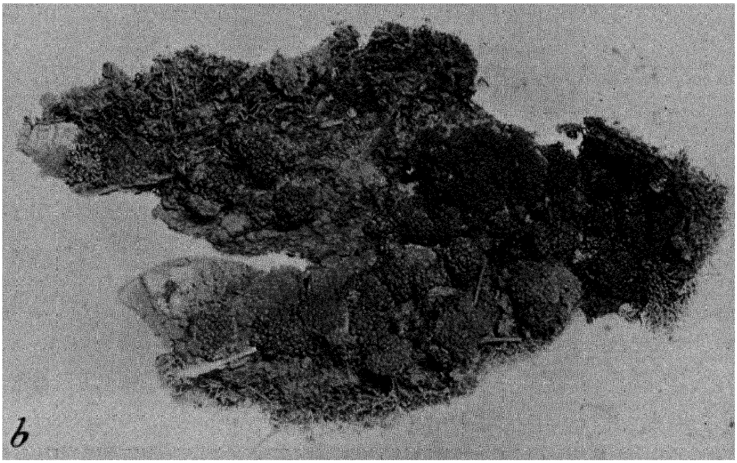


FIG. 9 *b*.—Flat fructification of *U. zonata*, growing together with *Kretschmaria* type of fructification. The *Ustulina* plates of typical form were growing out at the edges into the *Kretschmaria* forms.

and brittle, a close inspection will show that they bear scattered, minute, slightly elevated points. These are the openings into small, globose cavities, the *perithecia*, from which the black ascospores are ejected. After ejection, the groups of ascospores may often be seen resembling small, black heaps of dust, surrounding the ostioles of the perithecia.

When a mature fructification is cut or broken across, several distinct tissue layers can be distinguished. The conidial layer has disappeared, and the upper layer is black, composed of compact tissue very similar to that forming the black lines running through attacked woody tissues; below this black, compacted layer, is a white, loosely

compacted zone, in which the globular perithecia are formed, and below this is a broader band, grey in colour and leathery in consistency, and finally the lower surface is reached, this being formed by a continuation of the outer black zone on the upper surface (Diagram IV, 2).

The globose perithecia communicate with the exterior by very narrow channels. The first formed elements of the perithecia can be recognised in suitably stained sections very early in the development of the fructification, long before the production of conidia; these elements stain more deeply with protoplasmic stains than surrounding ones, and appear as small, circular patches of spirally running hyphae.

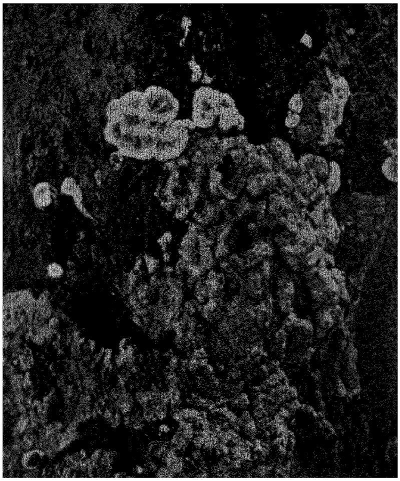


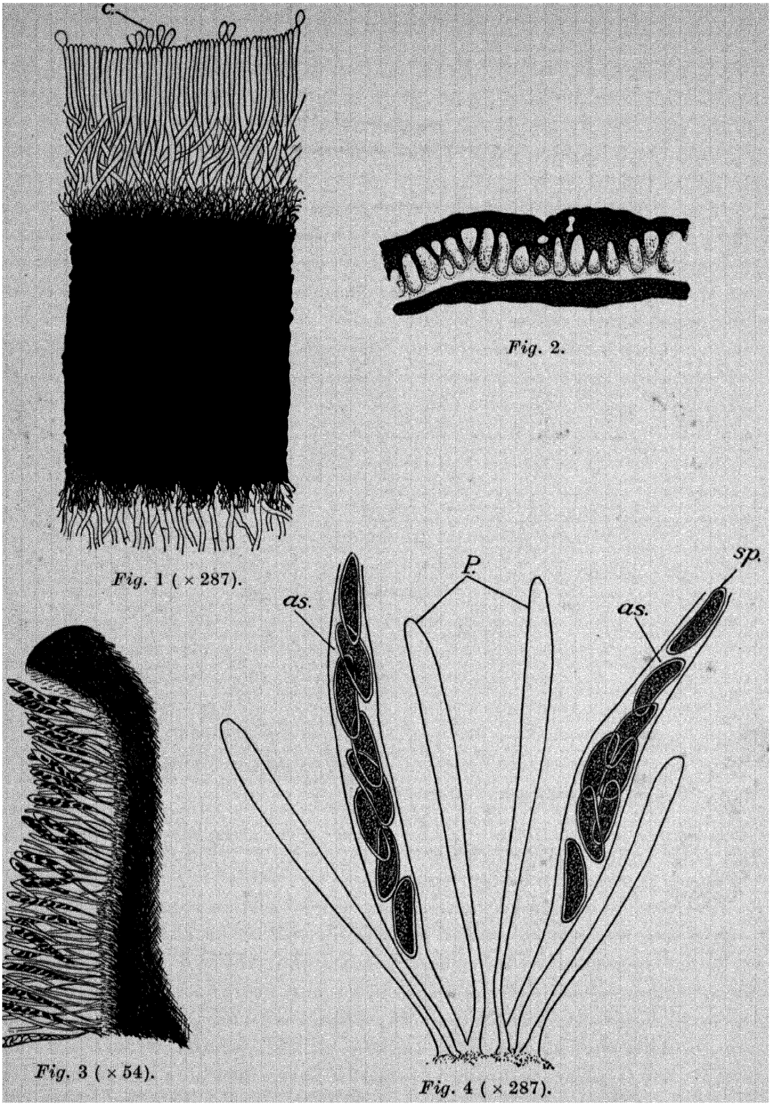
FIG. 9 c.—Fusion of flat fructifications of *U. zonata*, covering two square feet of stem at the base.

In the early stages of development the outer, black zone is not present in the fructification. Whilst the stroma is still soft and yellowish, the walls of patches of the loosely compacted layer, irregularly distributed, but at the same depth, become impregnated with carbonaceous material. Later, the walls of the fungal cells of the loosely compacted layer intervening between the black patches, become impregnated with similar material, their cell contents darken, and a continuous black, brittle zone is formed.

The greenish-grey conidial layer is formed about the time the black zone is completed, while the fructification, though leathery, is still soft. In many cases the conidial layer can be found on the younger, growing edge of the fructification, while the older parts in the middle are showing the ostioles of the perithecia. The conidia, when examined singly, are hyaline, but when present in large numbers and compacted to form a continuous surface, they give the upper surface a greenish-grey appearance. They measure $4\mu \times 2\mu$.

The perithecial openings can be observed as minute black spots almost immediately after the disappearance of the conidial layer. By this time, the black zone is continuous, and the spore chambers are

DIAGRAM IV (after Steinemann).



Ustulina Zonata

Fig. 1.—Section through conidial layer of young fructification. Diagrammatic representation of upper surface with conidia. × 287. *c*=conidia.

Fig. 2.—Section through older fructification. Showing upper surface after disappearance of conidial layer. Note globose perithecia in the substance of the fructification.

Fig. 3.—Enlarged view of interior of perithecia, showing asci, with ascospores and paraphyses. × 54.

Fig. 4.—Enlarged view of Fig. 3. × 287. *P*=paraphyses, *as*= asci, *sp*= ascospores.

developed just below this zone, in the more loosely compacted tissue. The asci are numerous with paraphyses (Diagram IV).

The ascospores, when first delimited from the remainder of the cell contents in the ascus, are hyaline, with no special contents. Later they darken, become almost black, with two or three oil drops. The mature ascospores measure 28–32μ × 7–10μ. In the writer's experience, the ascospores do not germinate readily, but germination of the conidia is more easily obtained.

There is much variation in the form of the fructifications. Petch reports the same feature from Ceylon. There is a solitary stalked form, the conidial layer being produced only on the top and continued for a short distance down the side. The commonest variation is the *Kretschmaria* type of fructification, in which the heads of a stalked form are crowded together to form a continuous, flat upper layer. Several investigators have considered a fungus named *Kretschmaria micropus* (Fr.), Sacc., to be a wound parasite on *H. brasiliensis*. The ascospores of this fungus measure about the same as those of *U. zonata*, as given above. Petch gives three records, viz. 28–33μ × 6–7μ, 29–34μ × 6–9μ and 28–32μ × 9–11μ, in an article entitled "Xylariaceae Zeylandica", published in the *Annals of the Royal Botanic Gardens, Peradeniya*, vol. viii., May 1924. This close agreement in size of the ascospores raises suspicions as to the specific identity of *K. micropus*, for both Van Overeem and the writer have called particular attention to the *Kretschmaria* stage of *U. zonata*, for it is often found both in pure culture and in close association with the ordinary plate-like form of the fructification in nature (Fig. 9 *b*). There seems no adequate reason in the present stage of our knowledge for considering the *Kretschmaria* fungus associated with symptoms similar to those attributed to *U. zonata* as other than an expression of the extreme variability of the external growth forms of the fungus. Petch gives a detailed description of different *Kretschmaria* species in the above-mentioned article, but the details are unlikely to interest planters; it should be consulted by any investigator who is desirous of finally settling the question.

There is another form of *U. zonata* which closely resembles a foliose lichen; this has not yet been found to produce spores.

Distribution.—The disease is disseminated by wind-borne spores, which are formed in great profusion. It can only gain entry into the tree through wounds; the characteristic symptoms shown by stem *Ustulina* are a clear example of this. In its mode of life and the type of damage done in the root system of *H. brasiliensis* the fungus *U. zonata* differs considerably in its salient characteristics from the *Fomes*

group of root diseases. According to Napper, the main points of practical significance are:

(1) *U. zonata* develops on all sorts of rotting debris, whereas the species of *Fomes*, causing root diseases on rubber trees, can only develop in those trees they have attacked parasitically.

(2) *U. zonata* spreads aboveground by wind-blown spores, whereas the other type of diseases spread underground by means of special vegetative organs, the rhizomorphs.

(3) *U. zonata* is a wound parasite and can only penetrate through wounds or through unhealthy tissue. The other type, *Fomes* group, are not fettered by this restriction.

Reasoning from (1) and (2), it is seen that the centres of infection and the mode of propagation of *U. zonata* are both practically uncontrollable, and from (3) that control can immediately be effected by avoiding the development of unprotected wounds. In all these respects the disease caused by *U. zonata* differs diametrically from the root diseases caused by the *Fomes* group of fungi.

One observation of interest was made during 1933, when several cases of lateral roots of *H. brasiliensis* showed a mixed infection of *Ustulina zonata* and *Sphaerostilbe repens*, the characteristic symptoms of both fungi being quite obvious. The intimate nature of the mixed infection was such that there was no clear indication where *U. zonata* ended or began. The succession along the root was *S. repens* → *U. zonata* → *S. repens*.

Control.—The method of infection and spread must be understood before control measures can be advised. All authorities in Ceylon, Java and Malaya are agreed that the commonest seat of infection is at the collar of the tree. The original infection is brought about by wind-borne spores, and Steinmann gives his opiuion that the tree is often more or less seriously wounded at the base during changkolling,[1] and that it is probably due to this cause that most infections are found at the root collar. In Malaya, a general opinion is held that the accumulation of rubber as bark or earth scrap at the base of the tree for a long period of time, results in the suffocation of the cortical layers beneath, for such rubber pads are wholly air-tight, and it is believed that the best conditions for attack by *U. zonata* are thus provided. The fungus becomes established below the pads, spreads deep into the bole and along the adjacent laterals, giving rise to the dry-rot infections so frequently seen in mature areas.

The evidence for spread by root contact is given by Petch, who says:

[1] *Changkol* = a native hoe used in cultivation operations.

The prevalence of *Ustulina zonata* as a root disease of tea is due to the practice of growing *Grevilleas* through the Tea and felling them when they have grown too large. The fungus develops on the stumps of *Grevillea robusta* and travels down its lateral roots, passing on to any Tea root which happens to be in contact with the *Grevillea* roots. To a lesser extent the same happens when *Albizzia moluccana* is felled, but another root disease is more usual in that case. The first case of *Ustulina* as a root disease of *Hevea* in Ceylon was in an old Tea field where the Tea had been abandoned and allowed to die out. In that case the *Ustulina* undoubtedly spread from the dead Tea roots to the *Hevea*. In another case *Albizzia* and *Lunumidella* (*Melia dubia*) had been planted as shade trees along the roadsides of a Tea estate, and the Tea was subsequently interplanted with *Hevea*; after some years the shade trees were cut out, and in numerous instances the course of their lateral roots was marked by a line of dead Tea bushes and one or two *Hevea* either dead or attacked by *Ustulina*. On another estate *Albizzia* had been planted at the same time as the *Hevea*, and cut out later; many *Hevea* trees were subsequently attacked by *Ustulina*, and clear cases of infection of the tap root just below the laterals were demonstrable, where a dead lateral root of the *Albizzia* was in contact with a *Hevea*.

As *U. zonata* develops its fructifications luxuriantly on old rubber stumps and logs left after thinning, it is obvious that careless thinning-out would influence and encourage its prevalence to a marked extent. This latter remark also applies to *Ganoderma pseudoferreum*. Large fructifications of *U. zonata* have moreover been found on old jungle stumps ten to twelve years after felling the jungle.

The two most important factors which influence the prevalence of the disease are (*a*) the presence of pads of rubber scrap at the collar of the tree which may remain untouched for many years, and (*b*) allowing rubber stumps and logs to remain *in situ* after thinning-out. Injuries caused during cultivation operations must, of course, also be taken into account. If, therefore, all felled rubber timber and logs are thoroughly cleared out during the thinning-out operation, and the remaining trees are cleared of the earth-scrap at the base periodically, there would be few reports of serious attacks.

When the price of rubber is sufficiently high, planters are not keen on cutting out diseased trees which may be yielding a normal supply of latex on one side. The danger is obvious, for fructifications often develop on the diseased side. Several estates have undertaken the collection of fructifications as soon as possible after they develop. Some attempts have proved quite successful or, at least, the results have been considered satisfactory. Others have not had satisfactory results, the chief reason for failure lying in the personal equation. This factor is of the utmost importance and, in Malaya, it must

always be taken into account when offering recommendations for disease treatment on a large scale. After much patient work and a considerable amount of success, a certain line of treatment is recommended to planters, some of whom may be more or less indifferent to the outcome. The only remark that needs to be added is that the usual result of careless or indifferent treatment must be practical failure.

Most observers who have been in close contact with the collar disease on *Hevea*, caused by *U. zonata,* have considered the question of the application of tree surgery methods in dealing with individual cases. In 1914 the writer tried cutting out the diseased tissues and filling in with cement, concrete and brick-work. The chances of success were considered somewhat remote at the time. Some thirty cases were dealt with successfully but none of the trees are standing at the present date. The Rubber Research Institute of Ceylon recommended a method of this type from 1924 onwards, and described it and the possible reasons for non-success. The financial aspect again rules the situation and the method could not be considered economic at present-day prices of rubber (1933). Future developments will rule out the application of expensive methods of treatment designed to save individual trees now over twenty years of age; that, at least, is the opinion of the writer.

The development spoken of as "stem *Ustulina*", where entry to the stem of the tree is gained through large branches being broken off, is dealt with in the section headed Stem Diseases.

Petch says the treatment of this root disease should follow the usual rules for root disease in general, i.e. complete removal of infected lateral roots from the soil and running a trench round the infected area, while dead trees or stumps of any kind should be dug up and burnt. At the present date, more especially on old properties, the point that must be kept prominently in view is to clear the soil of all infective material. In treatment of individual trees, therefore, if it is desired to maintain the tree in the stand, the lateral roots which are found to be diseased should be cut off as close to the trunk as possible. They should then be followed up to their extremities and completely extracted from the soil. Any lateral roots from neighbouring trees with which the diseased roots come into contact, should be examined at the point of contact and, if found diseased, should be followed and completely removed from the soil. The soil area in which the roots have been ramifying should then be dug over to a depth of one and a half to two feet.

In treatment of this type it is most important that the diseased

trees should be inspected every week or so, so that any fructifications which might grow from the diseased tissues in the trunk can be quickly removed.

After some time, diseased trees will die or be blown over. The diseased tap-root and laterals should then be completely removed from the soil and destroyed, along with the stems and branches, unless, as sometimes happens, the estate is suitably located so that a market for firewood can be conveniently established. As remarked above, old rubber timber should be removed as quickly as possible.

The fungus *Xylaria thwaitesii* has been reported as the cause of a root disease of rubber trees in Ceylon (page 176), and it may serve some useful purpose to add here a few remarks by Weir. He states:

During estate visits planters have pointed out black, spike-like fructifications from one to two inches high growing on dead wood of wounds at the base of trees. These fungi belong to *Xylaria*, a genus closely related to *Ustulina*, and they also produce black lines in the wood. They frequently follow up wounding from sunscorch, leaf fires, mechanical wounds, or may sometimes be associated with *Ustulina* in the same canker. *As a rule these fungi are not of much importance*. The treatment is the same as that for *Ustulina*. The species so far recorded on dead wood of living rubber are *Xylaria multiplex*, *X. plebeja* and *Xylaria deserticola*.

It is interesting to note that the fungi cultivated by certain of the mound-building termites number among them species of *Xylaria*. In one case there was a definite connection between a nest from which *X. plebeja* was isolated and an infection by the fungus on the roots of a tree.

SPHAEROSTILBE REPENS, B. & BR.

The disease caused by this fungus is often known as stinking root disease, for attacked rubber roots and the surrounding soil have a particularly foul smell.

The first record of its occurrence in Malaya was made by Richards in 1912–13. In 1914 Brooks investigated it for a short time, but the only important conclusion which could be drawn from his work was that attempts at artificial inoculations were unsuccessful. The fungus is well known in Ceylon, both on rubber and on tea plantations, and was first found there in 1907. Petch says this fungus has never caused any widespread damage in Ceylon.

In Malaya, the disease is most commonly found on low-lying coastal or riverine areas. In fact, it is best seen following the flooding of areas carrying rubber trees, and *Sphaerostilbe* practically always causes extensive damage under such circumstances. The first large area found showing diseased trees attacked by *S. repens* after flooding,

was practically wiped out and resulted in the total destruction of nearly 200 acres of rubber. Since that date many cases have been notified. During 1931 the bund at Port Swettenham burst and the river flooded a few neighbouring areas for several days. A fortnight later, the water had cleared away and soon afterwards numerous trees attacked by *S. repens* were found. More recently, an area was deliberately flooded for several days with a view to aiding white ant control. The insecticidal powder, Paris Green, was being used to control the insect attacks, and this had been applied before the water was allowed to enter the areas. A few weeks elapsed, and hundreds of cases of the root disease caused by *S. repens* were found. An attempt was made to fasten the entire blame on the use of the insecticidal powder, but even if it was ancillary to the outbreak of the fungus, there is no doubt that if enquiries had been made as to the advisability of flooding, a negative answer would have been returned, and the danger of a severe attack of root disease caused by *S. repens* would have been predicted. But it is interesting to note that there were but few records of rubber trees being attacked by *S. repens* after the Pahang floods of 1926, which were extremely severe and prolonged. A few remarks relative to the Pahang floods are given at the end of this section.

The disease has seldom been found on high ground in Malaya, though Petch states it is not confined to the low country in Ceylon.

Brooks reports that the foliage of rubber trees affected by *S. repens* becomes thin and the branches gradually die back. The progress of the fungus being slow, a considerable time sometimes elapses before the whole of the collar or all of the lateral roots become affected, with the subsequent death of the tree. Although this may be the case with individual trees, in the most noteworthy attack seen by the writer, the attacked trees shed their leaves rapidly. Ten days before the leaf-fall began, there were no signs of the fungus attacking the roots, as indicated by the gradual dying-back of portions of the crown, and it was only the occurrence of sudden and heavy leaf-fall which led to an enquiry into the cause of the trouble.

Symptoms.—If the roots of a rubber tree affected by *S. repens* are examined, they can (if the affected roots have not been too long diseased) be distinguished from all other root diseases by the black, flattened rhizomorphic strands, which are usually found between the bark and the wood. The edges of the black, flattened strands may be tinged with pinkish pustules which are the imperfect fructifications of this fungus (Plate I).

When a suspected case of *S. repens* is being investigated, the foul

smell of the soil which is being dug over will be the first indication of the probable cause. When the diseased roots are inspected no external rhizomorphs will be found, but if the cortex is lifted, the black, flattened, usually radiating rhizomorphs will show up prominently on the surface of the wood. Even when the rhizomorphs have decayed, their former position is often indicated by the presence of corresponding dark lines on the wood.

The rhizomorphs are not confined to one position, i.e. between the

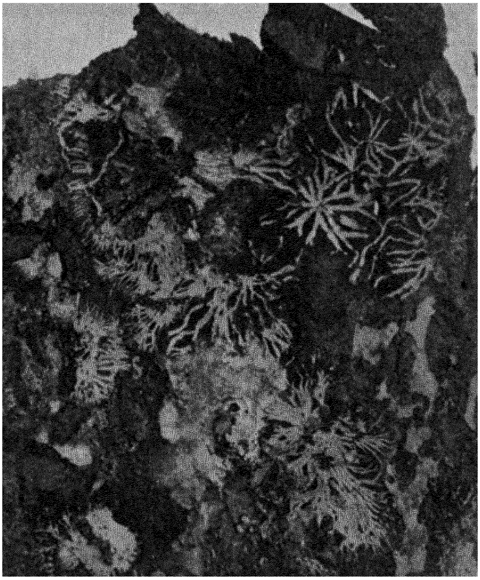


FIG. 10.—Radiating rhizomorphs of *Sphaerostilbe repens*, in cortex of diseased *Hevea* root.

wood and the outer cortical tissues, but they grow freely through the cortical tissues, and can often be found just under the external scaly bark (Fig. 10).

The aggregation of hyphae to form rhizomorphic strands of a microscopical character in the cortical tissues of an attacked root, as does *S. repens*, is a somewhat unusual feature in fungi. The centre of these microscopic rhizomorphs is either hollow or may consist of a few hyphae very loosely compacted together; these are surrounded by a layer much more closely compacted, and the latter is covered externally by an extremely dense layer of hyphae, which appear to

form a tough outer covering. They move through the cortical tissues of the host, splitting them apart as if a peg was being driven into them (Fig. 11). The appearance presented by sections of the cortical tissues of rubber roots attacked by this fungus is quite typical, and even if macroscopic rhizomorphs are few or entirely absent, the features described should be sufficient to establish its identity. A small rhizomorph is shown in longitudinal section in Fig. 11, while one in transverse section is seen in Fig. 12.

The rhizomorphs, as seen between the bark and wood, are usually about 2 mm. broad, but may reach a breadth of 5 mm. As explained

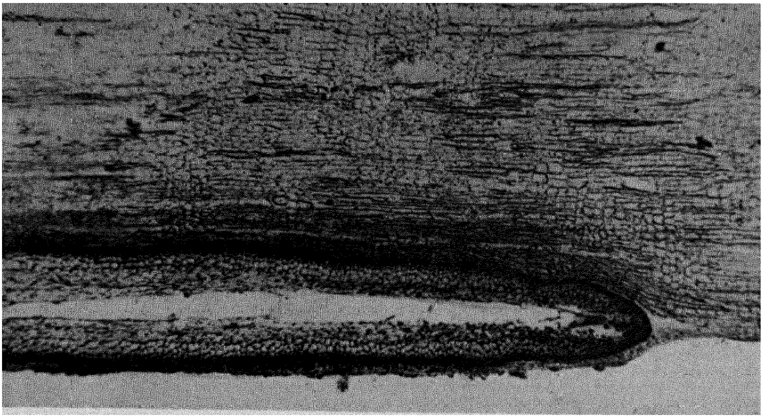


FIG. 11.—Longitudinal section through microscopical rhizomorph of *S. repens* in diseased cortical tissues.

above, the rhizomorphs may be microscopic, or may mass together to form large plates. When fresh and growing vigorously the general background of colouring of the large plates is greyish-white, with a reddish tinge in places, imparted by the presence of mostly imperfect fructifications. Later, they appear redder in colour, but as the root decays, so do the strands, and the latter become black. If the strands are not dead or moribund, they stand out prominently above the wood, but in old, decayed roots they may appear as a mere impression on the wood.

Petch describes the fusing of the rhizomorphs into a continuous sheet on a specimen found between the wood and bark of a decaying "Dadap" log (*Erythrina lithosperma*). It is evident that his remarks apply equally well to the fungus as found on *H. brasiliensis* in Malaya. He says:

In that case the rhizomorphs are much broader and they have fused behind into a continuous sheet. The outer surface of the rhizomorphs are marked with a peculiar herring bone pattern. When the bark was separated from the wood, these thick strands were often split horizontally, and the white internal tissue then presented a fern-like appearance. The patch of mycelium was over a yard in length and about eight inches broad, the separate rhizomorphs being evident only at the margin (Fig. 13).

Fructifications.—*Sphaerostilbe repens*, B. & Br., is a fungus belonging

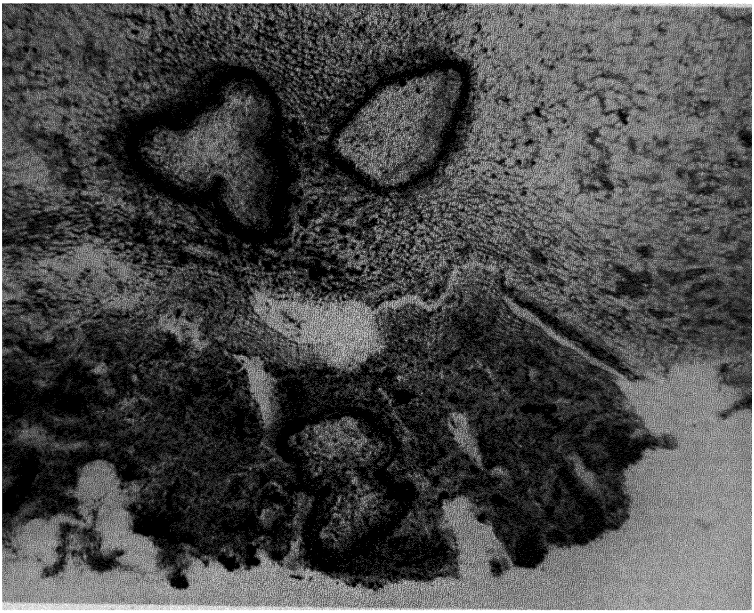


FIG. 12.—Transverse section through microscopical rhizomorph of *S. repens.*

to the Ascomycetes and so produces the perfect form of fructification characteristic of the genus *Sphaerostilbe*. These are small, dark red, globular perithecia, the asci therein containing eight one-septate spores. There is also a conidial form of fructification typical of a genus *Stilbum* which is placed in the *Fungi Imperfecti*. There are two other species of *Stilbum* found growing on rubber trees; one, *S. nanum*, Massee, is common on dead branches; the other, *S. cinnabarinum*, Mont., being, according to Petch and Brooks, the conidial stage of *Megalonectria pseudotrichia*, Schw. These species of *Stilbum* are much the same as the conidial form of *S. repens*, in having red stalks and

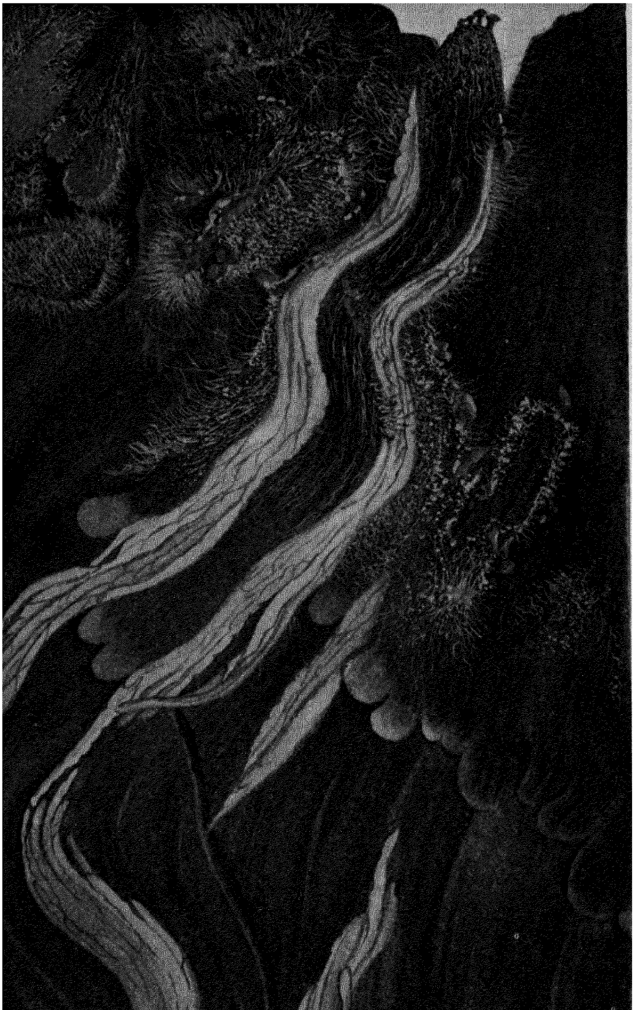


FIG. 13.—Mat of rhizomorphs of *S. repens,* formed by fusion. Found in diseased cortical tissues of roots. Note mat about to break up at edges into individual rhizomorphs. Also pink spores masses of *Stilbum* fructifications.

red or pinkish heads, but the stalk of the latter is hairy, whereas the stalks of the two former are quite smooth.

In the ordinary course of natural development the *Stilbum* stage of *S. repens* is the first to appear. It takes the form of short, erect, red stalks from 2 mm. to 8 mm. high and $\frac{1}{2}$ mm. to 1 mm. in diameter, surmounted by a white or pinkish, globose head, 1–1$\frac{1}{2}$ mm. in diameter (Fig. 14). They are formed in large numbers and can be easily seen when present. The stalk is hairy at first, but later becomes smooth in the lower half.

The writer doubts whether previous accounts of the development

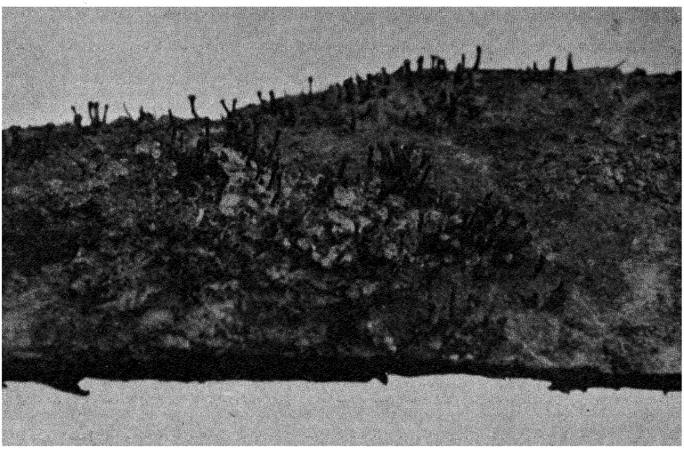


FIG. 14.—Typical appearance of *Stilbum* fructifications of *S. repens*, on rubber root. Natural size, slightly enlarged.

of the fructifications of *S. repens* can be considered to be more than a cursory statement, and further work must be undertaken before the position can be accepted as satisfactory. The actual method of the origin of the conidial fructifications, which has not been specially illustrated previously, is shown in Fig. 15. The section was taken longitudinally through a rhizomorph carrying the conidial fructifications. It will be seen that the upright masses of conidial hyphae arise not from the rhizomorph which is apparent on the surface but from the microscopical, submerged rhizomorphs which are formed in the cortical tissues of diseased roots; the surface rhizomorphs joining up the individual conidial heads also take their origin from a similar position. It appears as though the surface rhizomorph puts down root-like structures at varying distances, and from these the heads of the

conidial fructifications grow upwards. It is a matter of considerable morphological interest but space will not allow further comment. The spores which arise at the extremities of the *Stilbum* type of fructification are hyaline, oval, 10–20$\mu \times$ 5–9μ in size.

The perithecial stage of the fungus follows the conidial stage on diseased roots, but is not always to be found, for under certain conditions this type of fruit-body is not produced. Recent cases have been examined where there were numerous perithecia but no signs of the *Stilbum* stage. The perithecia are small, red bodies, rounded below and conical above, globose, about 0.6 mm. high and 0.4 mm. in diameter.

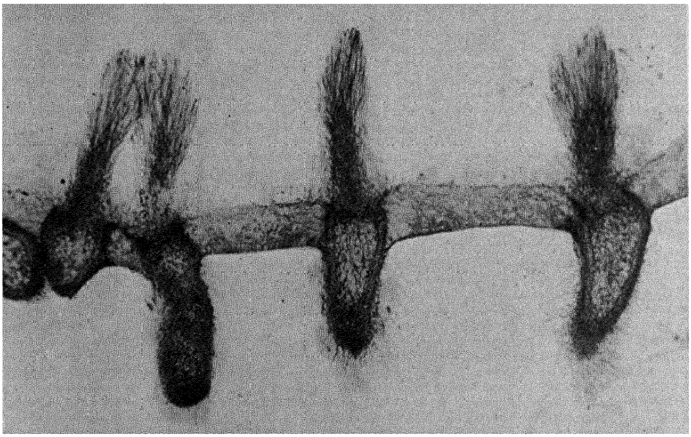


FIG. 15.—Section through diseased cortex of rubber root showing the *Stilbum* fructifications. Note their development from submerged rhizomorphs and that they are joined together by surface mycelial tissue. × 45.

The ascospores are contained in asci, 190–220$\mu \times$ 9μ in size, and the spores are eight in number, one septate, pale brown to reddish-brown, oval, slightly constricted, and measure 19–21$\mu \times$ 8μ.

Both Petch and Brooks state that *S. repens* can live entirely on dead plant tissues as a saprophyte. The writer has never specially noted this feature and it seems that further evidence would be required before the statement could be accepted.

Brooks, working in Malaya in 1914, successfully established pure cultures, and endeavoured to fix the status of the fungus as a parasite or saprophyte by artificial inoculations. In his pure cultures, sessile aggregations of spores of a yellowish-pink colour arise on both media (potato agar and rubber wood blocks), and these are often arranged in concentric zones. These spores were hyaline, oval and very variable

in size, the average limits being $16–20\mu \times 6–8\mu$, though some are much smaller.

In these cultures, spherical, thick-walled, resting spores were formed in the hyphae and at the ends of short branches; these spores are brown in colour when mature, and measure $9–10\mu$ in diameter.

In the inoculation experiments, sixteen plants were inoculated but after five months none showed signs of infection. This points to the possibility that some condition which predisposes some plants of *H. brasiliensis* to susceptibility must exist before the fungus can invade a healthy tree. The most probable factor is the inadequate aeration of the soil in areas where the requisite conditions are not provided for adequate drainage.

Dissemination.—The fungus can be freely spread by the wind for the spores are produced in large numbers on the conidial fructifications. Spread by root contact may be possible but this is not a prominent feature, as it is in *Ganoderma pseudoferreum*. Since it is fairly obvious that the fungus can successfully attack *Hevea* only within very narrow limits, it will evidently never cause serious damage unless the necessary conditions are provided.

There is not the slightest doubt that the requisite conditions are provided during, and after, flooding of low-lying plantations. It is a practical certainty that, if rubber trees remain standing in water, to a depth of nine inches or more, for a period of seven to ten days, the direct outcome will be a more or less severe attack of *S. repens*. Once a good hold is obtained by the fungus upon the roots, little can be done beyond extracting the diseased trees as far as possible.

Even when there has been no flooding, a single individual, or even three or four diseased specimens in close proximity, may occasionally be found. Dead trees must be dug up and burnt in such cases, and diseased stumps and lateral roots extracted. The fungus seldom attacks young trees; mature trees are usually the victims and as root contact has probably been made, it will be advantageous to trench around diseased trees in the customary manner. Further, as most of these cases occur on areas with heavy clay soils, the application of lime can be usefully recommended, for the soil acidity will be reduced, and flocculation of the clay particles will take place so that the soil can be broken up more easily. Both of these points are important if the denuded area is to be re-supplied.

The latest contribution to our knowledge of *S. repens* is from Ceylon, in 1929, by Small and Bertus. The discussion of results in this paper introduces the subject of the fungus *Rhizoctonia bataticola* in relation to root diseases of plantation crops, including rubber, and may

perhaps be usefully quoted at this point while comment upon the controversial issues may be reserved. It will be seen that in respect of *S. repens* the position in Ceylon is very much the same as that in Malaya, though if a "consequent suffocation of the roots of affected woody plants" is taken as the main predisposing factor which encourages infection in rubber plants, it is difficult to explain why no reports of trees killed by *S. repens* were received after the subsidence of the Pahang floods, for all forms of life must have been suffocated by the tremendous amount of silt deposited. The extract is as follows:

The results of the above experiments showed that *Sphaerostilbe repens* was able to attack arrowroot, *Canna* and papaw under the conditions imposed and that it was unable to attack the healthy roots of woody plants like tea, rubber and dadap, or of rubber and cacao seedlings, even with the supposed help of wound entrances to tissues and close contact between inoculum and host surfaces.

From the practical point of view the question of the attack of *Sphaerostilbe* on roots of woody plants is of greater interest than the question of *Sphaerostilbe* disease of arrowroot, *Canna* and papaw, and the remainder of this discussion therefore deals with the woody-plant aspect of the subject in hand. The lack of positive results in experiments with woody plants agrees with the negative results obtained by Brooks in experiments with rubber in Malaya. The investigator is forced thus to the conclusion that successful *Sphaerostilbe* attacks on the roots of woody plants is conditioned by the previous operation and effects of adverse physiological conditions which are presumed to produce in the exposed plant such a state of degeneration or lack of resistance that *Sphaerostilbe* is enabled to assume a parasitic role. In nature the adverse conditions seem to be supplied most frequently by lack of drainage and a consequent suffocation of the roots of affected woody plants, and it is possible that a moist or wet soil is the most suitable substratum for *Sphaerostilbe*. On the other hand, it is to be noted that the attempt to imitate natural moist soil conditions in the experiments did not lead to *Sphaerostilbe* attack on woody roots and that the fungus is found in nature in plantation soils which do not suffer from lack of drainage. It is not forgotten that the attempts to imitate moist soil conditions in the experiments may have fallen far short of natural conditions in their results. At the same time, it may be doubted if the moist soil conditions said to be required for successful *Sphaerostilbe* attack are in constant and regular operation in nature.

It is, therefore, in order to enquire into the possible presence and operation of other factors which may cause the necessary preliminary degeneration or unhealthy condition of woody roots required for *Sphaerostilbe* attack, and it has to be reported that, as already mentioned, a root disease factor is present with such frequency in Ceylon cases of *Sphaerostilbe* root disease that it must be taken into account. In short, it is probable that in many cases of *Sphaerostilbe* attack on woody roots, if not in all, the entrance and advance of the *Sphaerostilbe* is preceded by a diseased condition

induced by *Rhizoctonia bataticola* attack. The grounds on which the attack of the *Rhizoctonia* is assumed to be prior to that of other fungi found on diseased woody roots have been discussed with reference to *Fomes*, *Poria* and other forms, and they need not be repeated in this place. The writers, therefore, do not deny that *Sphaerostilbe* attack on woody roots may be a secondary phenomenon which follows upon moist or sour soil conditions, but they think it is necessary to lay stress upon the necessity for investigation into the possibility of the presence of *Rhizoctonia bataticola* either with and without the abnormal soil conditions.

Remarks on the Pahang Floods, 1926–1927.—The Pahang floods of 1926–27 will always be remembered by those who went through that terrible experience. It will be interesting to give a typical record obtained on a rubber estate, taking one from near Kuantan, in Pahang, as a suitable centre. The important point is that after extremely severe flooding few records of rubber trees attacked by *S. repens* were received. In view of the importance attached to flooding, some attempt must be made to account for this, though in typical cases of *S. repens* attacks following flooding, the floods are not usually severe or of long duration.

The estate in question was flooded on four occasions between December 21st, 1926, and March 4th, 1927; they are described as follows:

Dec. 21st–24th, 1926 . . .	Normal floods
Dec. 26th, 1926–Jan. 7th, 1927 . .	Abnormal ,,
Jan. 23rd–25th, 1927 . . .	Normal ,,
March 6th–10th, 1927 . . .	Normal ,,

The so-called normal floods gave a depth of water in the fields varying from 4 ft. to 30 ft., while, during the abnormal flood, the depth of water varied from 60 ft. in the deepest part to 2 ft. in the lowest. An acreage of 2300 acres was affected by normal floods and one of 3000 acres by the abnormal flood.

After severe and prolonged flooding very serious damage might be expected. During the Pahang floods a large quantity of silt was carried down and the depth of silt deposited in the depressions on the rubber plantations varied from 6 ins. to 16 ft. The average height reached by the deposited silt was 4½ ft. to 5 ft.

The chief troubles recorded were as follows:

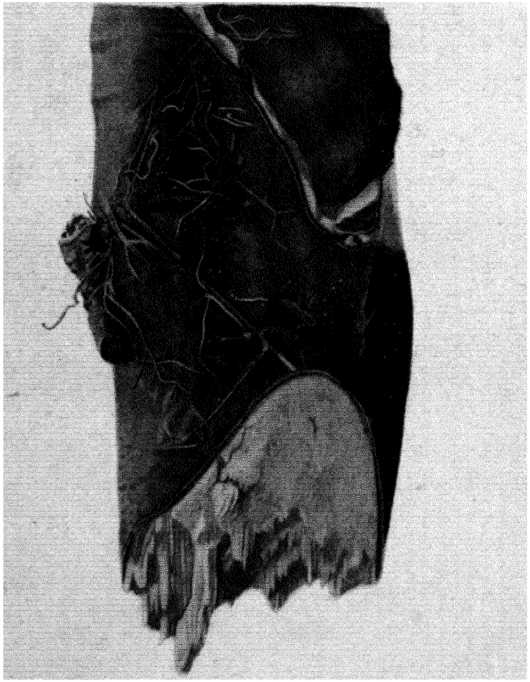
(*a*) Pink disease and claret-coloured bark canker became prominent when mature trees were submerged for a lengthy period, while those deep in slime showed a splitting of the bark with the free exudation of latex. The latter trees recovered after about one month.

(*b*) Submerged trees show the cortex affected just below and above the tapping cut, and in a few instances the affection descended to ground-level. Where the cortex had died down to the wood, soft pads of coagulated latex were formed between the wood and cortex, while both wood and cortex were of a blue-black colour.

(*c*) Trees were blown down by the cyclonic winds usually experienced during heavy flood periods, more especially on estates with loose soil, and as a result large numbers of other trees were injured by branches being broken away from the stems.

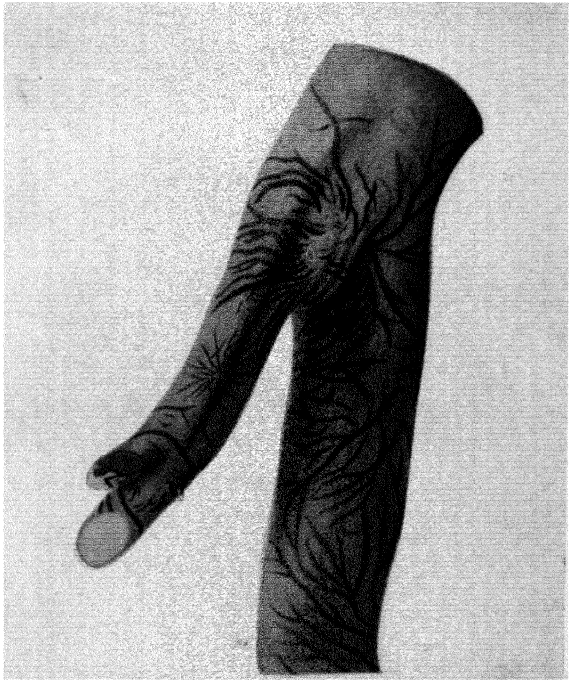
The deposit of large quantities of silt will undoubtedly have a suffocating action on all organisms living in the soil, and will necessarily have a very effective retarding influence on any new development of root disease below soil-level, caused by fungi. Silt will be easily removed from the trunks and branches of trees during ordinary rainy periods and there need be little fear of the bark or cortex being severely damaged as a result of silt remaining too long on the trunks and branches. Young trees are more affected by submersion over a lengthy period than mature trees, and in the majority of cases are killed out. The general amount of damage done on areas affected by severe flooding is usually large, but it is fortunate that in the particular case described, the deposit of fine silt filtered into the soil, changing the soil conditions to such an extent that they became distinctly unfavourable to the growth and development of any fungi which might cause dangerous root diseases.

Even if the trees are not blown prostrate during severe flood periods, the swaying of the trees during heavy winds on estates with a loose soil may result in the root systems being considerably damaged. Reductions in yield of 100 lbs. per acre were reported from estates affected by the Pahang floods by this cause, and many months elapsed before the trees recovered to give their normal yield by the development of new, small feeding rootlets.



Ganoderma pseudoferreum

Typical appearance of rubber root well rotted by *G. pseudoferreum*. Note purplish discoloration produced by development of external rhizomorphic membrane and brownish discoloration of wood.



Sphaerostilbe repens

Surface of wood of diseased root attacked by *S. repens*, exposed by removal of cortex. Showing typical, black, flattened, radiating rhizomorphs, on surface of wood.

CHAPTER IX

FOMES LIGNOSUS—GANODERMA PSEUDOFERREUM—FOMES NOXIUS

FOMES LIGNOSUS, KLOTZSCH
(*White-root Disease*)

THE root disease caused by this fungus has been prominent in Malaya since the first plantations were opened up. During the years 1910–16 this disease was by far the most important which had to be dealt with, and the losses were often so numerous that, before the disease could be brought into subjection, large sums of money had to be expended in control measures. Steinmann reports:

> In recent years, two Sumatran estates with an area of 2750 acres, about 70,000 trees, were destroyed and another estate lost about 15,000 trees.

In Malaya, we have recently dealt with areas showing a percentage loss of nearly 18 per cent over 700 acres. It is now known that much of the money expended in the past on control measures for the disease caused by *F. lignosus* was not profitably spent, for the results obtained did not prove to be of permanent value, and any control established was really due to natural factors, chiefly those affecting the manner of growth and spread of the fungus. This subject will be enlarged upon later when presenting treatment of the root diseases caused by *Fomes* spp.

Petch states:

> This disease was first recorded in Malaya by Ridley at Singapore in 1904. In Ceylon it was first recorded in 1906. The absence of any previous record in Ceylon is doubtless due to the fact that much of the earlier Ceylon rubber was planted among Tea or Cacao, and that some of the earliest plantations were established on land which had been cleared of almost all the jungle stumps prior to planting.
>
> The fungus has been reported from South India, Java, Sumatra and Borneo and in West Africa and the Congo region. The disease does not appear to have been recorded from the Western Hemisphere, but as the fungus is known to occur throughout the tropics, it will, no doubt, ultimately be found wherever it (rubber) is grown.

The disease is not often prominent on mature areas in Malaya, though losses due to *F. lignosus* are common on some coastal proper-

ties. But wherever and at whatever period a recrudescence of new planting occurs, the disease springs into prominence. During the last few years, a considerable amount of new planting of bud-grafted rubber has been undertaken, and an opportunity has thus arisen for studying this disease intensively.

Symptoms.—The fungus is readily identified by its external rhizomorph system. The white hyphae of the fungus become aggregated together to form stout, smooth cords, which are firmly attached to the surface of the roots (Figs. 17 *a* and *b*). They run more or less longitudinally along the root and unite here and there to form a network. These cords may vary slightly in colour according to the colour of the soil in which the rubber plants are growing, but in artificial cultures the rhizomorphs of *F. lignosus* are pure white. In the field, however, they may be white, or yellowish-white, or in red laterite soil, reddish. They vary in breadth, but the thickest are seldom more than ¼ in. thick. The rhizomorphs may spread out into forms of hyphae which unite into a continuous sheet; this usually takes place at the point of the limit of growth of the fungus on the root, and forms the younger, growing parts. This type of mycelial aggregate is often found at the collar of the plant, but the fungus seldom appears above soil level. Even if it does, it is seldom conspicuous, for the strands become subdivided into finer threads or even separate hyphae which can only be detected with difficulty at the base of the stem. The writer has, however, recently seen specimens showing a conspicuous white mycelium, which formed a complete cover from ground level to a few inches up the stem. After careful examination it was concluded that the mycelial cover, in this case, was a type of Thread Blight (page 286).

The typical rhizomorphs are more or less rounded on the upper side and consequently stand out conspicuously on roots which have been affected for some time. The external cords give rise to threads which penetrate into the roots and bring about their decay. But this penetration is not immediate.

Petch recognised this feature many years ago for he says:

> The superficial mycelium frequently spreads for some distance along a root before penetrating it.

Because of this there exists the possibility of treating and saving roots which are already showing the external rhizomorphs, by scraping the latter away with some sharp instrument. So that for a certain length of time the fungus is merely attached to the bark of the root in the manner of an epiphyte. Recently, De Jong has published some

work relating to field inoculations and has pointed out that in two field experiments, 57 trees, $3\frac{1}{2}$–$4\frac{1}{2}$ years of age, and 126 trees, 5–7 years of age respectively, were found to be infected naturally; they had mycelium of *F. lignosus* on the roots but they did not show decay. In 60 per cent of these cases, the mycelium disappeared without any treatment and without doing any harm. This is a very different result to the one from which Petch draws his conclusion when he says:

> Taking all circumstances into consideration it is probable that the majority of trees attacked die within twelve months.

De Jong draws the conclusion from his observations that the fungus is but weakly parasitic on rubber trees and that it can cause extensive decay only under special environmental conditions. Weir states an opposite view as follows:

> Studies on the parasitism of *Fomes lignosus*, *Fomes lamaoensis* and *Ganoderma pseudoferreum* conducted under controlled and uncontrolled conditions show that *Fomes lignosus* is strongly parasitic and is capable of causing the death of six-months-old rubber without the supplementary action of any other organism.

Therefore it appears that the later work of Weir would support the views held by Petch, but the field work done in Malaya over the last three years supports De Jong's observations.

It is very important to realise that the percentage number of trees showing mycelium on the roots is not a suitable criterion for the results of field experiments; the only reliable one is the percentage number of trees actually lost as a result of becoming infected with the fungus. This very critical basis of computation has been adopted in Malaya, as will be seen in Tables II and III. While accepting De Jong's results and conclusions, it must be kept in mind that the reaction of young roots to the presence of the fungus may be very different to that found in roots of trees which are several years older, in so far as it may be possible that the epiphytic stage remains more persistent in younger or older trees, as the case may be.

Apart from the external rhizomorphs, attacked lateral or tap-roots show no particularly distinguishing features. As stated previously, a wet-rot may be found in cases, but if it is not a mixed infection with white ants, the infected wood remains fairly firm, but obviously penetrated with mycelium. Where white ants are common, mixed infections are frequently found.

The spread of the fungus in the roots of young trees progresses up to a point when the supply of water to the leaves is greatly reduced. Whilst the leaves are green a sufficient quantity of water to maintain

life is passed up the tree, but when the limit is reached and the root system cannot supply the necessary amount of water required, the leaves wilt rapidly, turn brown, and death ensues within a few days.

Attention should be directed here to the fact that rhizomorphs of fungi other than those of *F. lignosus* are found in the soil of rubber plantations and even on rubber roots. The rhizomorphs of *F. lignosus* can be distinguished because they are tightly attached to the root, while the others are only loosely attached and easily removed. These saprophytic fungi which form rhizomorphs are quite common in the soil; the cords are usually slightly coloured in shades of purple or yellow.

Petch reports that, in Ceylon, when *F. lignosus* was first found, the fungus was most frequently associated with stumps of Jak (*Artocarpus integrifolia*) or various species of *Ficus*. Hence it was presumed, at one time, that it would be unnecessary to remove all stumps in order to avoid the occurrence of this disease, and that it would be sufficient to adopt a method of selective stumping and to get rid of the stumps of trees which were known to serve as hosts for the fungus. Bancroft, in Malaya, later concluded that this fungus occurred indiscriminately on all kinds of stumps. The fructifications have been found on various plants, including several species of palm.

The following host plants are notified by Van Overeem:

Anona squamosa, L.; *A. glabra*, L.
Areca catechu, L.; *Artocarpus* sp.
Artocarpus integrifolia, L.; *Afzelia* sp.
Bambusa sp.; *Bambusa spinosa*, Roxb.
B. vulgaris; *Berrya* sp.; *Bombax* sp.
Cordya mixa, L.; *Cyclostemon* sp.
Cocos nucifera, L.; *Coffea* sp.
Cinnamomum sp.; *Cinnamomum camphora*, Nees
Derris sp.; *Dendrocalamus* sp.
Erythrina indica, L.; *Ficus* sp.
Ficus benjamina, L.
Gliricidia sepium (Jacq.), Steud.
Hevea brasiliensis, Mull. Arg.
Koompassia sp.; *Leucaena glauca*, Benth.
Livistona cochin-chinensis, Mart.
Mangifera indica, L.; *Malotus* sp.
Manihot Utilissima, Pohl
Oncosperma sp.; *Oncosperma filamentosa*, Blume
Palmae; *Pterocarpus* sp.

Polyalthia sp.; *Shorea guiso* (Blanco), Blume
Strychnos nux-vomica, L.
Theobromae cacao, L.; *Thea*; *Vitex* sp.

Petch supplies the following list, several of which are included in Van Overeem's citations:

Common Name	*Scientific Name*
Meranti	*Shorea* sp.
Merbau	*Afzelia palembanica*, Baker
Kumpas	*Koompassia malaccensis*, Maing
Bombax	*Bombax malabaricum*, D.C.
Dadap	*Erythrina umbrosa*, H.B.K.
Halmilla	*Berrya ammonilla*, Roxb.
—	*Derris dalbergioides*, Baker
Ceara rubber	*Manihot glaziovii*, Mull-Arg.
Serdang palm	*Livistona cochin-chinensis*, Mart.
Nibong palm	*Oncosperma filamentosa*, Bl.
Giant bamboo	*Dendrocalamus giganteus*, Munro

The fungus has also been recorded as causing a root disease on Tea, Camphor, Liberian and Robusta coffee, Tapioca, etc. Petch remarks that the records cover such a wide range of flowering plants that any selective method of stumping is impossible. This is quite true, but in the writer's experience in Malaya, "Kumpas" trees are by far the worst for harbouring *F. lignosus*. Cases have been observed where the rhizomorphs could be removed in huge quantities from the neighbourhood of the buttress roots of "Kumpas" trees. In areas where these trees have been numerous in the jungle, special attention should be given to their stumps as a source of propagation from which *F. lignosus* commences to spread.

White-root disease begins to come into prominence between the first and second year. It has been known to cause considerable losses in seedling nurseries, but in the field the plants reach an age of about eighteen months before any definite signs of the fungus can be observed. Development from this point is rapid, and if the area is heavily infected and control measures are neglected the loss of stand may be very large. This is of more immediate importance at the present time than formerly, for newly planted areas are invariably filled with good planting stocks upon which expensive material is bud-grafted later.

The infection spreads from diseased jungle stumps and rotting jungle material derived therefrom, which exists in the soil at the time

of felling and burning. *F. lignosus* is an exceedingly vigorous and mobile fungus, with a diffuse, far-spreading, rapidly growing rhizomorph system. The fungus is a quick-acting wood destroyer and the affected roots rot away rapidly after felling. The attack on the succeeding rubber plantation therefore develops quickly after planting, is widespread and usually dies down before the trees reach maturity. For these reasons the disease is represented characteristically on immature areas, but should any factor delay the rotting away of the

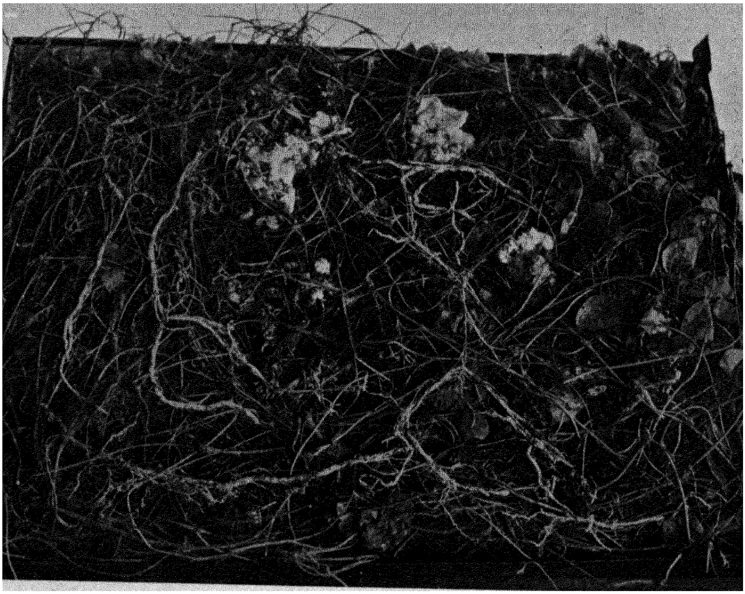


FIG. 16.—Showing rhizomorphs of *F. lignosus* growing amongst roots of cover crops.

infected jungle timber, or if control measures are neglected until trees are of an age when their roots form an interlacing system all over the planted area, then the disease may cause excessive damage in the mature stand.

Napper considers that only those stumps of the trees which were attacked in the jungle before burning are of any importance in spread and that stumps of trees which were free from the fungus in the jungle are no longer dangerous after burning, for they cannot be infected by wind-borne spores of *F. lignosus* and therefore cannot act as hosts. This definite statement appears to be directly contrary to the state-

ments made by Petch in his 1921 edition. In addition, the latter investigator makes a definite statement in relation to the independent travel of the mycelium through the soil which Napper does not agree with. Petch's statements, therefore, can be conveniently extracted and considered at this point:

The spores of the fungus are blown on the exposed wood of the stump, and if the weather conditions are favourable they germinate and their hyphae grow down into it. These hyphae continue growing in the dead tissue until they have permeated both the stem and the roots, and then they spread from the roots of the stumps to the roots of adjacent living trees. Some fungi can only spread to other plants if the roots of the latter are in contact with those of the host stump; others, however, can spread freely through the soil, drawing food from the supply in the stump which served as a base. Each stump thus affords a centre of disease, spreading disease in ever-widening circles.

Later he states, with reference to *F. lignosus*:

Thus, the time when the disease is first evident on the rubber depends to a great extent upon the time taken by the fungus to destroy the jungle stumps, or perhaps more correctly, on the time taken by it to accumulate to such a degree that it is able to spread further afield. *It may also be dependent upon the time taken by the rubber to develop lateral roots since the fungus will then have a shorter distance to travel to reach them.* It is not, however, necessary that the lateral roots of the rubber should come in contact with the diseased roots of the stump, because the mycelium of *F. lignosus* can travel independently through the soil.

Petch further states:

It is the fact last mentioned which makes this disease so formidable and makes its eradication so difficult. The majority of fungi can only advance within dead wood, but the strands of *F. lignosus* can travel for a few feet at least through the soil unattached to any root or dead wood, except, of course, at their starting point. It is always attached to its base, i.e. the stumps on which it originated, and it must derive its food from that source until it meets with other dead wood, or a living plant which it can attack. In all probability it will die if separated from its base, unless it soon meets with fresh material from which it can derive nourishment.

Free mycelium is usually found in the uppermost foot or eighteen inches of the soil, etc. etc.

On the same point Steinmann states:

The danger of White-Root mould (*F. lignosus*) is aggravated by the fact that detached pieces of mycelial strands (so-called rhizomorphs) can remain alive in the soil for a long time even when lacking organic food and so can spread from a bit of dead wood left in the soil.

Napper's recent researches in Malaya lead him to consider that, as far as that country is concerned, the disease becomes first evident when the tap and lateral roots of the young rubber trees have attained sufficient length to penetrate into the disease knots, formed by the presence of diseased jungle stumps and timber left after felling and burning. This is the prime feature of importance with regard to the origin of the disease. As shown by the extracts, other investigators do not particularly emphasise this feature, though Petch evidently recognises the possibility of the growth in length of tap and lateral roots being of some importance in the spread of the disease. Emphasis is usually laid on the spores being blown on the exposed wood of stumps, which then becomes infected on the germination of the spores, or upon the question of the independent travel of the mycelium through the soil, which is said to make the disease very formidable to control, and its eradication difficult. The recent work in Malaya provides exceedingly strong evidence that these features can be considered, at most, of very minor importance. Hundreds of diseased trees have been carefully opened up, even to depths of four feet, and in every case, without a single exception, the diseased material, from which infection has spread, has been found in contact with the diseased roots at some point. This diseased material is always either a jungle stump or material derived therefrom, which is actually being rotted by the fungus penetrating the internal tissues, and it is found in contact with rubber roots which were previously healthy, but which have become infected at the point of contact. Some typical cases of diseased jungle roots, in contact with rubber roots which have become badly infected as a result, are shown in Fig. 17 *a–c*.

In many cases the source of infection was difficult to detect, but as experience was gained the diseased jungle roots, carrying infective material, were always found. There is no doubt in the writer's mind that, for Malaya, Napper's evidence on this particular point can be fully accepted, and that possible infection of stumps by wind-blown spores and independent travel of the mycelium or rhizomorphs through the soil can be entirely subordinated when considering the most suitable method of control. Even if it was admitted that the mycelium and rhizomorphs of this fungus had power of independent movement through the soil, it would be difficult to consider this of any great importance. There has been such a large number of serious outbreaks which have been dealt with entirely successfully by simply keeping in mind that digging must be continued until the actual source of infective material has been discovered and extracted. In every single case where operations have been guidedby this recommendation

FIG. 17 *a*.

FIG. 17 *a*, *b*, *c*.—Illustrations showing infected jungle timber in disease "knots", with roots of rubber trees which have contracted infection as a result of increase in length by natural growth.

Note photograph (*a*): the piece of infected jungle timber lay some nine inches below the lateral root of the rubber tree and it was difficult to detect the point of contact between the two pieces of infected material for the lateral root of the rubber tree was undoubtedly infected. At point marked *A*, a minute hair root, hardly discernible in the photograph, was found descending from the rubber root to make contact with the infected wood below. The appearance in the field was that here was a case of the spread of the infection by the free passage of a rhizomorph from jungle timber to a rubber root. However, a transverse section quickly showed the typical root structure surrounded by the mycelial felt of the fungus.

FIG. 17 *b*.

feet in length, may be formed by the close intergrowth of single fructifications (Plate II and Fig. 18). When fresh, the fructifications grow out horizontally to form the typical bracket shape, but when dry the edges curl up and the fresh deep orange colour of the upper surface fades to a dull grey. A resupinate form of the fructification is often found.

The brackets, when fully formed and in the fresh condition are leathery or even woody in consistency, with a more or less definitely

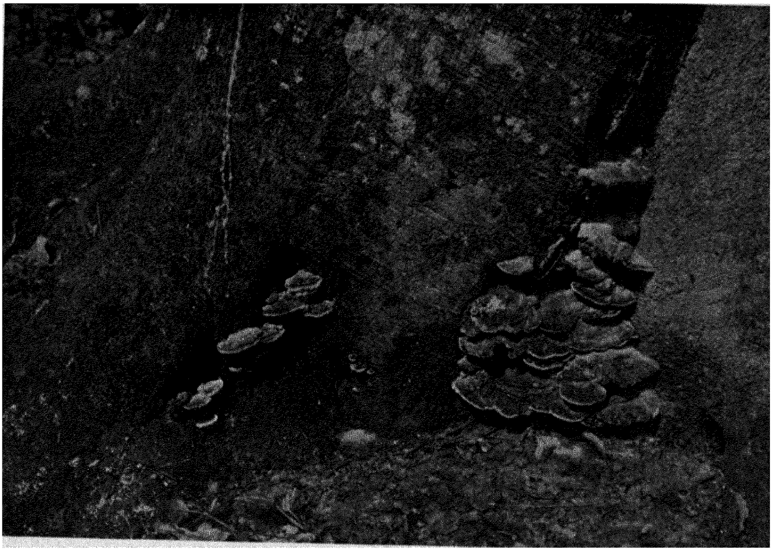


FIG. 18.—Illustration showing development of fructifications of *F. lignosus* growing at the collar of old rubber tree.

zoned, orange-yellow, upper surface. When the zoning is not very definite, the upper surface usually shows a deeper colour (Plate II). There is often a radial, fibrous appearance on the upper surface, and the edges of the fructification form a definite, bright yellow, or yellowish-white rim. The under surface is coloured orange. The size of the brackets vary considerably; the usual size is between 2 and 5 ins. in the longer axis and 1 and 3 ins. in the shorter. When the fructifications dry out, the colour becomes duller, the upper side turns pale yellowish-brown, the bottom side red-brown, and the yellow colour of the rim fades away, and the edge turns downwards.

If one of the fructifications is cross-sectioned, two clearly defined

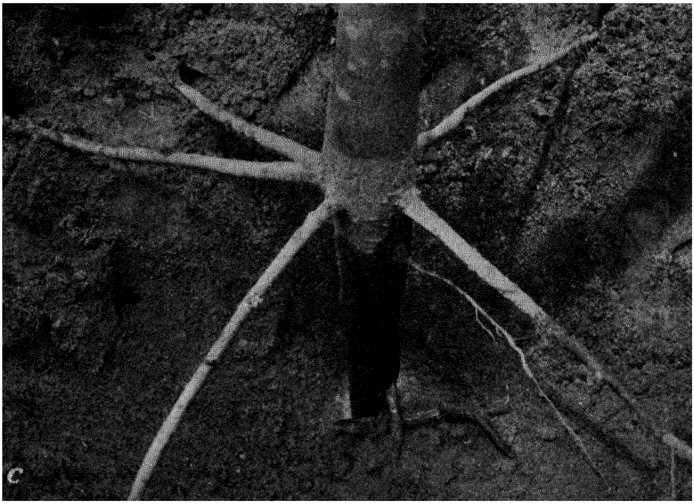


FIG. 17 c.

Note (c). This shows a tap-root infection from a small piece of infected wood, only about one foot long, and no other infected wood could be found in the vicinity. This also illustrates the depth to which digging had to be carried before the sources of infection could be found, in many cases.

the results have been considered satisfactory from an economic standpoint. It seems an undoubted fact therefore that, for extensive spread in rubber plantations, there must be a continuous chain of living, susceptible roots in direct contact with diseased jungle timber.

Petch makes two remarks which might be quoted here:

(*a*) Infection by spores has been considered improbable, because when the fructifications have been examined they have been found to bear very few spores, or in some cases, none at all,

and

(*b*) this is probably merely a matter of examining the fructifications at the right stage.

Napper has recently set all doubts at rest on this point in Malaya, for he has found copious spore discharge at certain periods of the year. Judging from Steinmann's book, there has never been any doubt upon this point in Java.

Fructifications and Spores.—The fructifications, as seen in nature, are of the usual, bracket-shaped *Fomes* type, unstalked, being attached to the substratum by a broad base. Simple, single fructifications are the most common, but compound fructifications, several

feet in length, may be formed by the close intergrowth of single fructifications (Plate II and Fig. 18). When fresh, the fructifications grow out horizontally to form the typical bracket shape, but when dry the edges curl up and the fresh deep orange colour of the upper surface fades to a dull grey. A resupinate form of the fructification is often found.

The brackets, when fully formed and in the fresh condition are leathery or even woody in consistency, with a more or less definitely

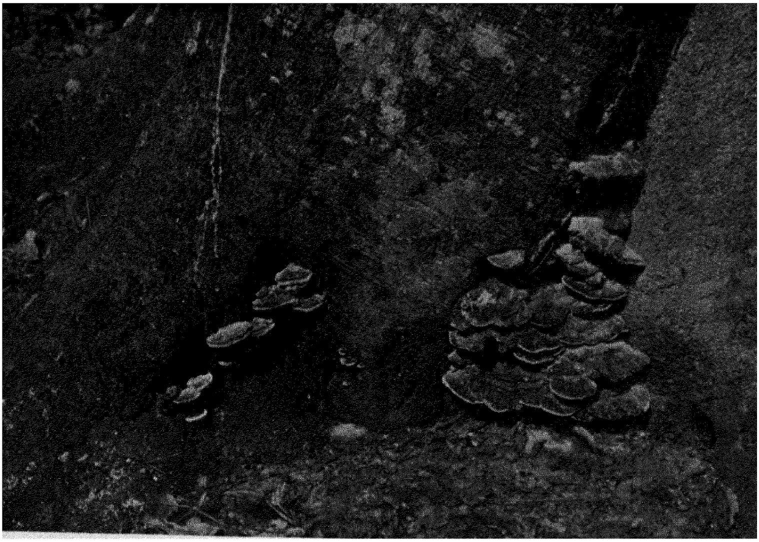


FIG. 18.—Illustration showing development of fructifications of *F. lignosus* growing at the collar of old rubber tree.

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If one of the fructifications is cross-sectioned, two clearly defined

layers, each of a different colour, can be seen; an upper, whitish, light-coloured layer, built up of closely interwoven hyphae, and below an orange-coloured layer of tubes or pores in which the spores are formed and from which they are discharged when ripe. The upper light-coloured layer and the lower orange-coloured layer may be taken as distinctive for *F. lignosus* by the planter, for there is no other *Fomes* species in the plantations showing these characteristics; at least, none has been reported up to date.

The pores are 45–80μ in diameter, bright orange-yellow when fresh, and on drying up, discolour to a dirty grey. The length of the pore tube varies considerably. While some doubt has persisted in Malaya in past years as to the fertility of the fructifications, there is now no reason to believe that they are sterile. They produce viable spores in large numbers under certain climatic conditions, which probably occur at least once a year and last for a considerable period. The occurrence of infection, as a result of the wind dispersal of spores, may therefore be considered highly probable in Malaya, but further work is necessary correctly to value how far this method of propagation influences the spread of the disease.

The spores are colourless, spherical, 2·8–8μ in diameter, and according to Steinmann are always present in large numbers in young fructifications. The spores may have completely disappeared from old fructifications.

The basidia are thick-set, colourless, and at the tip bear four fine sterigmata on which the basidiospores are borne. They are about 16μ long and 4·5–5μ thick. Among the basidia, club-shaped, colourless, thin-walled cystidia are to be found here and there.

Control and Treatment.—It has already been emphasised that the future treatment of the *Fomes* group of root diseases in Malaya must be of a comprehensive nature, for these diseases are closely linked under field conditions, and treatment for *F. lignosus* cannot be undertaken without reference to the root disease caused by *Ganoderma pseudoferreum*. The latter becomes prominent after the disease caused by *F. lignosus* has reached its peak and is on the decline. The position is different in Ceylon, for the disease caused by *G. pseudoferreum* has not yet been recorded; at least it is not included in the list of rubber diseases of Ceylon published by Murray in 1930.

In order to deal with this group of root diseases in the manner defined, it will be necessary to detail the various points which have influenced recent investigators in Malaya to take up almost an opposite attitude to previous workers. In addition, the views generally held up to a recent date may be stated here; these are given in

paragraphs (*a*), (*b*), (*c*), (*d*) and (*e*), which follow. The general theory is dealt with at this point because the important features came into prominence when investigating *F. lignosus.*

(*a*) All the fungi of the *Fomes* group which cause the main group of diseases of the rubber tree have evolved a successful means of vegetative propagation by means of rhizomorphs.

(*b*) In the past, it has been generally stated, particularly in the case of *F. lignosus*, that the rhizomorphs can travel independently through the soil.

(*c*) That each jungle stump affords a centre of disease, spreading disease in an ever-widening circle.

(*d*) That spores of the disease-causing fungi are blown on the exposed wood of jungle stumps and, under favourable conditions, the spores germinate and the hyphae grow down into them. The roots of these stumps thus become permeated with the fungus, and it spreads from them to the roots of adjacent living rubber trees. Some fungi can only spread to other plants if the roots of the latter are in contact with those of the host stump; others, however (such as *F. lignosus*), are supposed to spread freely through the soil.

(*e*) On the above basis, isolation trenches to prevent spread of the disease in area were indispensable.

As a result of his recent work, Napper puts forward the following suggestions:

(1) That the centres of infection which appear in the plantations represent the places in the jungle where the disease-causing fungi have attacked individual trees or groups of trees before the felling of the jungle is undertaken.

(2) These disease centres, where the fungi have gained dominance in the jungle, are absolutely fixed by the acts of felling and burning, and they are considered to form a kind of network the meshes of which would conform to uninfected areas of land which did not carry previously infected jungle trees, while the knots of the meshwork represent areas of ground in which infected jungle stumps would be found. Hence, distribution of root disease in the jungle at the moment of felling governs entirely the distribution of centres of infection in the subsequently planted crop.

(3) With the networks thus predetermined in size or area, and the "meshes" being smaller or larger, and the "knots" of infection fewer or greater according to the varied activities of the fungi concerned, the only method of spread is by contact of healthy roots with infective timber. It is thus the growing roots of the planted rubber trees

which *disclose* the "knots" of infection at a greater or less period of time.

(4) This leads to the interesting conclusion that in the early years of the plantations, until root-contact amongst the stand of rubber trees is established, isolation of diseased trees by trenching is unnecessary, and is really waste of money. When root-contact between neighbouring trees is fully established and knots of infection are still present in the soil, then trenching can be effectively undertaken.

(5) Thus, in the early years, the apparent spread of the disease amongst the rubber trees is, in reality, a false spread, as it is entirely governed by the spread in ground area of the roots of the rubber trees brought about by natural growth. The disclosure of the infective knots thus brought about by natural increase in length of roots is a sound conception, for only time is required ultimately to bring a healthy root into contact with infective material in one of the knots, and no system of trenching can prevent this.

From these premises Napper draws the following conclusions:

The first relevant point is that the old conception of root-disease fungi as living and moving freely in the soil must be discarded, and with it the cognate idea that the function of an isolation trench is to separate diseased soil from healthy soil. The SOIL is always healthy, even if it contains infected timber. The root-disease parasites live in decaying wood, not in the soil itself, even their organs of propagation, the rhizomorphs, being unable to make direct entry into the soil, but being constrained to travel along the surfaces of buried roots. If this is so, isolation trenches are successful only in so far as they cut through the chains of roots between infected and uninfected areas. In a young area, before root-contact has become established between neighbouring rubber trees, isolation trenches perform no useful function whatever.

The second point to notice is that the centres from which root disease develops in a clearing are determined in position and extent *before ever the jungle is felled*. While it was held that root-disease fungi could live and move freely through the soil and could spread also by the infection of the exposed ends of jungle stumps by wind-blown spores, disease patches were looked upon as the outcome of simple radial developments of sporadically occurring point sources of infection. The practice of throwing isolation trenches around the sites of dead trees was therefore entirely justified, as it aimed at preventing unlimited development of these point sources. It is now known, however, that the centres of infection are the knots of jungle-tree infection and are therefore neither point sources nor sporadic in occurrence, but are already delimited at the time of felling. No amount of trenching can prevent their "spreading" to their predetermined size.

The type of "spread of infection" typical of the early days of an attack is therefore a false spread. It does not represent enlargement of the infected areas, but the gradual disclosure of these areas as the expanding

rubber-tree root systems make closer and closer contact with the buried infected timber within the limits of the knots. It is obvious that isolation trenches must be powerless to prevent spread of this kind.

It is only when the full extent of the knots of jungle infection has been unfolded that true spread of infection, controllable by the use of isolation trenches, can begin, and even then it is dependent upon the existence of free root-contact throughout the stand of rubber trees.

These specific conditions are not fully satisfied in a rubber plantation until the stand is 12-15 years of age. During the first five or six years after planting neither condition is fulfilled and isolation trenches are therefore worthless, while during the subsequent five to ten years they become gradually more and more useful until full practical utility is reached at the age stated above. In younger stands, say up to ten years of age, the use of isolation trenches, even where they can be justified, should be entirely subordinated to a policy of discovering and eradicating the knots of jungle infection. Such a policy is fully practicable (it has been tried out already on a field scale), and of course would obviate both the present and future need for isolation trenches by removing the actual sources from which infection arises.

There has been considerable divergence of opinion in the past as to whether the money spent on the treatment of white-root disease would be economically disbursed. On the majority of estates in Malaya, the position is much the same as that described for white ants (page 377). The disease appears in the early stages of the plantation: during subsequent years there is a sudden increase in numbers of trees attacked until a peak is reached about the fifth year, when a decline sets in and the disease either practically disappears or at least is not prominent to any great extent. The doubts respecting the economic treatment of the disease caused by *F. lignosus* are quite justifiable, more especially when the procedure followed is to plant a sufficiently large number of trees per acre to allow for disease losses, so that not too large a proportion of the stand could possibly be lost before the trees were ready for tapping. If an optimum stand per acre can be ensured, this may be considered a good and sufficient reason for continuing this method.

In Malaya, the position has been entirely changed by the writer's discovery that *Ganoderma pseudoferreum* was capable of attacking the youngest trees, and Napper, following on this, demonstrated that it was present in the earliest stages of the plantations, just as in the case of *F. lignosus*. Attention is drawn later to the fact that young rubber trees in Java were found suffering from the root disease caused by *G. pseudoferreum* in 1930. They were reported by E. Von Zboray, who gave their age as four and a half years old. The only difference in the two fungi is that *F. lignosus* is a quicker-growing fungus, becom-

ing prominent from the second to fifth year, whereas *G. pseudoferreum* does not attain prominence until about the tenth year or even later. The enormous amount of damage brought about in old rubber areas in Malaya must be put down to *G. pseudoferreum*, and if the future is to be assured, a scheme of control is necessary which will reduce losses to a minimum from both *F. lignosus* and *G. pseudoferreum*. A suitable scheme has been worked out and all preventable losses from root disease should now be accounted for. If this optimistic view of the future is realised, then the expense of early treatment of root disease will be fully justified.

The following remarks regarding early treatment must be taken to apply equally for the disease caused by *G. pseudoferreum* and that caused by *F. lignosus*, although the latter shows up more prominently in the early stages. If the situation is taken in hand about a year after planting, much can be done before diseased trees begin to appear. At this stage the connections and contacts between the jungle-root systems can still be traced with ease, while infected jungle roots still bear unmistakable evidences of infection. If, therefore, a systematic collar inspection is made of all jungle stumps, it is possible, at this early stage, to map out the "knots" of infection and, by digging out all the infected stumps, entirely to eradicate root disease of all kinds once and for all, before any appreciable loss of stand has occurred. This method has already been tried out on a large scale, and on one estate is proving satisfactory.

If control measures are deferred until their need becomes apparent, i.e. until rubber trees begin to die, the opportunity of making this single clean sweep of root disease will be lost. The connections between the jungle roots will rot away, thus rendering it difficult or impossible to trace infection from stump to stump, while the progressive decay of the stumps themselves will make it difficult to distinguish between uninfected and infected stumps which have lost the traces of the rhizomorphs which originally caused their infection but have not yet begun to develop rhizomorph systems of their own. In such cases, methods have to be devised by means of which the infected timber is discovered and removed piecemeal. The simplest of these is the method of periodic tree-to-tree inspection, with treatment which will lead to the tracing and removal of the sources of infective material. This generally consists of bits of rotting timber lying at various depths in the soil, usually not deeper than two feet, though cases have been observed where the infective material was found at a depth of four feet. In order to guarantee complete control with this system, tree-to-tree inspection is absolutely essential.

It is impossible to detect an infected tree on leaf symptoms alone, until it is beyond hope of treatment. The tree can then neither be saved itself nor can its own removal as a source of infection be of any great benefit to its neighbours, since each infection in a young stand is a separate one, the decay of the "knots" having left each one an area of scattered, unconnected infective material. It is a case, therefore, of every tree for itself, and it is only by making a tree-to-tree inspection that infected trees can be caught at an early enough stage to yield to treatment. Furthermore, the treatment must be periodic, since a tree which is healthy at one inspection may, within a few months, as its root range increases, make contact with hitherto untouched infective material in its vicinity. As regards frequency of treatment, the rounds must be frequent enough to ensure that, in the interval between consecutive rounds, the number of trees becoming too heavily diseased to yield to treatment is small compared with the number which can be treated successfully. In practice, an interval of four months between inspections works well, even in cases of very heavy infection.

It has been stated above that the discovery and eradication of the jungle knots of infection is of vital importance if a successful system of control is to be developed, and that the disease knots of both *F. lignosus* and *G. pseudoferreum* must be removed as completely as possible. The actual method of procedure may now be given in detail. We will select for treatment a young budded area the soil of which is covered with a thick cover crop of *Centrosema pubescens*, and control measures should be started when diseased trees are first found. The following instructions should be carefully noted:

(1) In order to avoid damaging the trees all excavations in the vicinity should be made by a wooden shaft, which is shaped like a spade at one end and pointed at the other.

(2) The cover crop must be removed to a distance of three feet all round the trees.

(3) The root systems of the inspected trees must be laid bare to a depth of eighteen inches to two feet below the collar and laterally three feet from the stem.

(4) A thorough examination of the exposed roots is now made. If they prove to be infected, the source of infection should be sought for. Commencing at the stem of the tree, the various lateral roots are bared to their entire length until contact is made with the infecting stump or piece of rotting timber. Any stumps which have to be removed are usually found with the white rhizomorphs growing on

the surface. Usually a tree is infected from one stump only, but this must be carefully checked, as there may be other seats of infection. The soil surrounding the stump and the infected tree or trees is then dug over to a depth of eighteen inches and small fragments of jungle timber removed. Enormous quantities of this are often found and are usually covered with the mycelium.

(5) When the roots of the rubber trees are found carrying the white rhizomorphs, the latter should be carefully removed by means of a clasp-knife or other sharp instrument, and the underlying cortical tissue carefully examined to see if it is discoloured owing to the penetration of the fungus into the tissues. If there is no discoloration and the cortical tissues seem healthy, the root system should be completely drenched in a solution of 2 per cent copper sulphate. The roots are then gently rubbed to remove all traces of infection.

(6) Paragraph No. (4) refers to trees in which the mycelium has not penetrated into the underlying plant tissues, i.e. the fungus is in the epiphytic state. When the fungus has penetrated into the root, discoloration of the underlying tissues will be observed. Such cases demand the removal of the diseased root, and the application of a wound cover such as tar or asphaltum-kerosene mixture on the cut end. When this procedure has been thoroughly carried out, the earth is replaced and packed down in its original position around the roots.

(7) It is advisable to distinguish between (*a*) trees inspected and (*b*) trees found diseased. A black mark is suitable to indicate the former; a red mark to indicate the latter.

The following is typical of a detailed analysis of a tree-to-tree inspection. A patch (A) was examined which contained 327 trees, bud-grafted exclusively with clone A.V.R.O.S.50. The majority of the trees presented a vigorous and healthy outward appearance with good growth and girth for age. Prior to the commencement of the tree-to-tree examination, two cases of white-root disease had been located and treated.

Fifteen trees were found to be infected by *F. lignosus* on the first examination = 4·6 per cent. Some trees carried a heavier infection than others, but none appeared beyond the aid of treatment. When the infection is light and there is no penetration of the root tissues by the fungus, there is no difficulty and most of these trees seem likely to survive.

In the more heavily infected trees, certain of the lateral roots had to be removed, the exposed wood surface being treated with tar. The costliness of the operation depends on the degree of difficulty entailed

in the search for submerged timber harbouring the mycelium. In some cases cartloads of heavily infected timber have been found and removed, whereas in others the surrounding ground has been found to be comparatively free, apart from the actual disease "knot" itself.

Of the 15 cases found it should be noted that all were single trees except in one instance where two infected trees were found together. These were somewhat evenly distributed over the area and there was nothing which indicated the presence of disease prior to the actual examination of the root systems. In practically every case the foliage carried was ample and of healthy appearance. Incidentally, the sporadic appearance of diseased individuals strongly supports Napper's contention that the disclosure of the infected area is brought about by the expansion of the root system; as the roots grow in length they, at some time or other, come into contact with infected material, and infection is not brought about owing to independent travel of the white rhizomorphs through the soil. If the white rhizomorphs could travel independently through the soil to any large degree, the resultant distribution of diseased trees would obviously be of a grouped character.

A second patch (B) containing 484 trees budded with clone A.V.R.O.S.49 was treated in a similar manner to patch A. The trees were all thoroughly healthy in appearance, but the branching and girth development were not so good as that of the bud-grafts of A.V.R.O.S.50. Again, the large majority of the trees found to be infected were single cases. Two cases of two adjacent infected trees, and one group of seven infected trees, were found. The amount of submerged timber uncovered again varied largely.

The percentage of infected trees found in this patch was approximately 8 per cent = 38 out of 484 trees. This is a heavier percentage infection than in patch A, and in addition the individual cases appeared to be more heavily infected. All the treated cases in patch A appear to be maintaining a healthy foliage after treatment, but three in patch B died after treatment.

Over the areas examined, the sources of infection in the disease knots were usually found at a depth of 2–3 ft., although, occasionally, digging to a depth of 4 ft. was necessary. Thus it is obvious that the expense of these operations will vary considerably according to the depth at which the infective material is found. Expenses will also vary according to the age of the trees; it is much more costly to open up the root system of a four- to five-year-old tree than a two-year-old tree because of the much greater extent of the former. Further, expenses

will vary according to type of soil; it is much more expensive digging in heavy clay soils than in open sandy loams.

An analysis of the records received from an estate which has been systematically treating root disease, under supervision by Napper, shows many interesting pointers. The experiment is in progress on an estate of 3000 acres, divided by purely artificial boundaries into three clearings, each roughly 1000 acres in extent, planted in 1928, 1929 and 1930 respectively. The land is constant in type throughout the whole area and originally carried heavy jungle.

The site has many advantages from an experimental point of view. In the first place, the uniformity of the site makes it reasonable to assume that the jungle carried, before felling, a uniform incidence of root disease throughout, and that the differences which have since developed between the types of attack in the three clearings have been due solely to the differences in manipulation to which they have been subjected. Since the areas compared are as large as a thousand acres, the error involved in making this assumption should be small. A second advantage is that the clearings are in distinct age classes with equal class intervals; and a third that, when the experiments were begun two years ago, Clearing No. 2 (planted in 1929) was just two years old and therefore at the period of maximum root-disease activity, while Clearing No. 1 (planted in 1928) was well beyond the maximum, and Clearing No. 3 (planted in 1930) well short of it.

The experiment was started in October 1931 and took the simplest form, viz. the application of a standard method of treatment over the whole estate. The method employed consisted of periodic rounds of tree-to-tree inspection and treatment as outlined above, the rounds following one another at intervals of three to four months. Treatment consisted in opening up infected trees, following the rhizomorph systems to their points of origin, removing the sources of infection (rotting jungle roots) and treating the roots of infected trees with a weak solution of copper sulphate.

The work has been wholly in charge of the Manager, and has, in fact, been carried out as a purely commercial operation under estate conditions. Personal visits have been paid as often as possible to discuss the progress of the work.

Up to the present (February 1934) there have been six rounds of treatment in Clearing No. 1, and five each in Clearings No. 2 and No. 3. Detailed records have been kept by the Manager for each round of treatment, showing the results of the previous round (i.e. recoveries, deaths and re-treatments), the amount of new infection and the cost of treatment. These records have been summarised in the following

table (barring costs, a full statement of which is not yet available):

TABLE II

Clearing	Present Age (in years)	Age at which Treatment began (in years)	Length of Time under Treatment (in years)	Loss of Stand before First Treatment (per cent)	Recoveries since Treatment began (per cent)	Loss of Stand since Treatment began (per cent)	Total Loss of Stand since Planting (per cent)	Present Incidence of Infection (per cent)
No. 1 (700 acres)	5	3	2	15·9	7·7	2·2	18·1	0·67
No. 2 (1200 acres)	4	$2\frac{1}{2}$	$1\frac{3}{4}$	8·9	7·7	2·3	11·2	0·49
No. 3 (1100 acres)	3	$1\frac{1}{2}$	$1\frac{1}{2}$	3·7	5·7	2·0	5·7	0·99

Allowing for the fact that Clearing No. 1 has received one extra round of treatment, the figures for the different clearings are remarkably consistent among themselves, and agree closely with expectation based on the present theories of root disease. It may be difficult at first to understand why the recoveries (and also the losses since treatment began) in Clearing No. 3 are not a good deal higher than in No. 2, and in No. 2 than in No. 1. The explanation is as follows. In young clearings, where the root systems of the trees are small, individual pieces of infected jungle timber are unlikely to infect more than one tree before being discovered and removed during treatment. In older clearings, however, the root systems are large and widespreading, and individual pieces of infected timber stand a good chance of infecting two or more trees before removal. In each clearing the treatment has saved a considerable number of trees from becoming infected, although there is no means of showing this type of "recovery" in the records. It is certain, however, that the number is much higher in Clearing No. 3 than in No. 2, and in No. 2 than in No. 1.

Table II indicates very forcibly the advantage of beginning treatment early. In Clearing No. 1, at three years old, in the complete absence of treatment, loss of stand had reached the alarming figure of over 18 per cent, yet in No. 3, at the same age, after being under treatment for eighteen months, the loss was barely a third of this figure, i.e. 5·7 per cent.

De Jong's recent work should be kept in mind at this stage, for if we accept for the time being that in 60 per cent of infected cases the mycelium disappears without causing harm, then the 18 per cent of total losses would represent a total infection of over 40 per cent. The

point made by De Jong is of considerable interest, but is not of great importance when considering control, as will be explained later.

A more accurate measure of the relative success of the treatment when begun at different times after planting is provided in Table III, which shows the state of affairs at the same age (i.e. three years after planting) in each clearing:

TABLE III

Clearing	Age before Treatment began (in years)	Loss of Stand before Treatment began (per cent)	Length of Time under Treatment before Stand 3 years old (in years)	Loss of Stand during this Period (per cent)	Total Loss of Stand at 3 years old (per cent)
No. 1 (700 acres)	3	15·9	..	..	15·9
No. 2 (1200 acres)	2¼	8·9	¾	1·8	10·7
No. 3 (1100 acres)	1½	3·7	1½	2·0	5·7

Although the experiment has not yet been completed there can be no doubt that, from a *scientific* point of view, it will prove a complete success. As regards costs, a full record is not yet available except for Clearing No. 1, and this will be given here as they are the most important. The total cost of five rounds of inspection and treatment, including the cost of cultivating the sites of dead trees, amounts to 3.20 dollars per acre. Considering that the total cost of bringing this particular clearing into bearing is estimated at 200 dollars per acre, and that for under 2 per cent of this expenditure an immediate saving of at least 15 per cent of the stand has been effected, to say nothing of the subsequent saving on account of the early removal of centres of infection of *Ganoderma pseudoferreum* (an even more important factor), there can be little hesitation in pronouncing the experiment a complete success also from the *financial* point of view.

It is stated above that De Jong's point when considering control is not of much importance. All cases affected, whether in the epiphytic stage, which would include De Jong's 60 per cent of harmless cases, or in the more advanced ones where penetration of the host tissues by the fungus has actually taken place, must be treated according to the routine laid down. It would obviously be dangerous if the treatment of epiphytic cases were delayed, for exposure of the root system should be of short duration, therefore the earth must be returned to cover the roots which are carrying, or have carried, epiphytic mycelium, as soon as possible. If left untreated, a serious attack may eventually result, for, as De Jong emphasises, the fungus mycelium can cause extensive decay only under special environmental conditions, and if such eventuate, any epiphytic mycelium may take on an active phase,

during which period penetration may take place. It must be remembered that environmental conditions are never static, but are continuously changing at different periods of the year. For this reason, it seems most undesirable that the figures given by De Jong should be allowed to influence any recommendations for control. Just as at certain periods of the year, and not at others, there is a profuse production of viable spores, in the same way, the passage of the mycelium on the roots from the epiphytic to the parasitic stage may be entirely under the influence of the climatic conditions prevailing at any particular period.

If De Jong's investigations can be confirmed by observations in Malaya, it is obvious that on lightly infected areas the disease caused by *F. lignosus* will not call for special treatment, and that it may be possible, as certain planters claim, to limit treatment to removing the roots and stems of the trees killed by the fungus and re-supplying immediately. But if this type of treatment is undertaken and no attention is given to eradicating disease knots of *Ganoderma pseudoferreum* in the early years, then it can only be expected that more time must be spent and further expense incurred when the trees are about the age of ten years. It cannot be emphasised too often that the recommendations now being made for treatment of *F. lignosus* are largely dependent on the fact that such treatment will also result in the early extermination of disease knots of *G. pseudoferreum*.

Much prominence has been given to the recent work of De Jong on the subject of *Rigidoporus microporus* (= *F. lignosus*). This investigator has carried out his investigations in Sumatra, while Napper has been working on the same subject in Malaya. The two investigations have practically coincided in time, but while the one in Malaya was devoted mainly to obtaining results which would prove useful in the control of a general root-disease problem, that in Java was considered from a different angle, for De Jong states specifically in the extract following that

> no attempt is made to deal with the practical side of the question, since it is considered that the *Rigidoporus* problem is one that can only be intelligently solved with a view to the peculiar conditions obtained in any particular locality and the results thus obtained are largely of local significance only.

It will be noticeable to readers that our conceptions of the root-disease problem in Malaya are mainly based on the very extensive damage which has been done generally in the old rubber areas by the root disease caused by *G. pseudoferreum*, and that, if it were not for this factor, De Jong's statement would meet the situation in Malaya,

with respect to the root disease caused by *F. lignosus*. There are many important results recorded in De Jong's work which, for all practical purposes, may be considered identical with those obtained in Malaya by Napper. Therefore, a copy of the most relevant portion of the English summary of De Jong's paper is given below for comparison with the points raised in the foregoing account:

The foregoing inoculation results experiments appear to indicate that the fungus in question is only weakly parasitic to rubber. The presence of mycelium alone on the roots of an infected tree does not necessarily indicate the subsequent development of decay, and the presence of decay is not always followed by the death of the tree. Observations to this effect have not only been obtained from the inoculation experiments but also from trees that have become naturally infected in the field. Of course there is no doubt that *Rigidoporus microporus* is frequently responsible for deaths in stands of Hevea, but such cases are probably associated with special environmental conditions that affect the virulence of the fungus and the susceptibility of the tree.

It would appear that the following factors are of importance in connection with the development of *Rigidoporus* decay in Hevea:

a. The presence of *Rigidoporus* decaying wood in close contact with the roots of the tree.
b. The size and/or quantity of the inoculating material. Probably the nature of the inoculating wood is also important.
c. Extent of decay of the inoculating material.
d. The size of the rubber tree involved, as small trees can be killed more quickly than larger ones.
e. Variation in resistance to the disease among rubber trees. This may be the result of predisposing environmental conditions.
f. Previous history of the area, with special reference to the vegetation it formerly supported. In this connection, epidemics have been observed in red soil areas that were formerly planted with *Ficus elastica*, also in red soil and sand "permatang" areas previously planted to coco-nuts. White soil areas that formerly supported coco-nut palms are apparently not particularly subject to the disease. The literature contains references to the effect that rubber planted on sites previously occupied by *Koompassis Malaccensis* and *Artocarpus elastica* is especially subject to the disease.
g. The situation with respect to ground cover. In this connection Napper reports that the incidence of the disease is reduced through the presence of cover crops, "blukar", and avoiding clean clearing in opening new areas. Although the importance of these factors is not precluded, they cannot be considered as definitely established, especially since Napper's method for estimating the status of the disease is open to question.
h. Characteristics of the soil. The rubber on red soil and sand "permatang" areas appears to be especially subject to the disease, where its incidence is very much higher than in the case of white soil stands. As far as

conditions on the H.A.P.M. are concerned, there appear to be no direct relationships between the incidence of the disease and:

I. the *p*H of the soil;
II. the titratable acidity of the soil after shaking with a potassium chloride solution;
III. the phosphate of the soil;
IV. the humus content of the soil;
V. oxidation characteristics of the soil.

i. Manuring treatment. In this connection, however, an experiment in a red soil stand of young rubber showed no significant differences in the disease situation following the application of the common artificial manures and certain combinations thereof, except in the case of treatment with a combined manure containing nitrogen, phosphate and potash, together with manganese sulphate, where an increase in the incidence of the disease was obtained. Even in this instance, however, it is considered that confirmatory evidence is required before accepting the fact as established. From another experiment it appeared that the use of a mixture of cow-dung and soil for filling the planting holes caused a slight increase in the incidence of disease among the young trees planted in this manner.

In the present paper no attempt is made to deal with the practical side of the question, since it is considered that the *Rigidoporus* problem is one that can only be intelligently solved with a view to the peculiar conditions obtaining in any particular locality, and the results thus obtained are largely of local significance only. At the same time, certain aspects which have been brought out in the present paper should not be overlooked in a practical study of the problem:

(*a*) An estimation of the disease situation in any particular area should not be based on the incidence of mycelium infections only, since the presence of mycelium is not necessarily followed by decay.

(*b*) The same is true with regard to judging the status of disease from a single examination as to the incidence of *Rigidoporus* decay, because such decay may stop of its own accord, even without treatment.

(*c*) The only satisfactory manner in which to estimate the disease situation in any particular locality is through repeated examinations that show the progress of decay, or better still, an accurate record of the mortality due to the disease.

Summary of Treatment.—It may be advisable, for the sake of the planter, to give a summary of the views expressed in the foregoing paragraphs.

Napper believes that if the situation is taken in hand not more than a year after planting, much can be done to deal with infected jungle knots before diseased rubber trees begin to make their appearance. As stated, this method has been used with beneficial results on a large scale on one estate, yet the writer's opinion is that it will prove

of limited application, because the personal factor will enter into the proposition to a very great extent. Usually, it is only when diseased trees are being discovered that the question of control is seriously considered.

The following fact has already been emphasised and explained in detail and should now be clearly understood by all readers; viz. that in a young area, before root-contact between neighbouring rubber trees has become established, isolation trenches cannot perform any useful function.

That the centres of infection are the "knots" of jungle-tree infection already delimited at the time of felling, and no amount of trenching can prevent their spreading to their predetermined size.

Further, spread of infection in the early days of an attack is not an actual spread and is really a gradual disclosure of diseased areas by the expanding rubber-tree root systems making closer and closer contact with the buried infected timber within the limits of the "knots". Isolation trenches cannot prevent spread of this kind.

Isolation trenches can only become useful when the full extent of the "knots" of jungle infection has been disclosed, and then their utility is entirely dependent upon free root-contact throughout the stand of rubber trees.

Thus, isolation trenches can be considered worthless during the first 5–6 years; during the next stage covering another 5–6-year period they will become more and more useful, until at the age of 12–15 years they will reach full practical utility and, as will be obvious later, will be specially useful in the control of the disease caused by *G. pseudo-ferreum*. Up to the age of ten years the use of isolation trenches should be entirely subordinated to a policy of discovering and eradicating the knots of jungle infection.

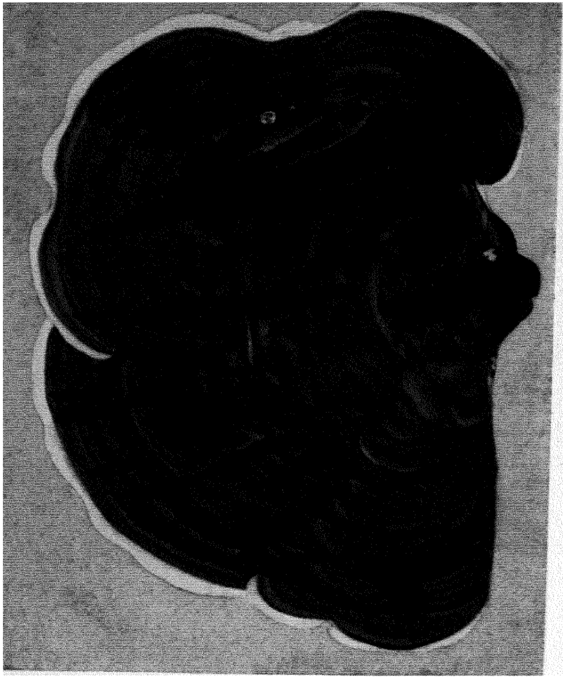
Three points may be briefly emphasised:

(1) It is obvious that there should be no trenching.

(2) There is no necessity to use lime except under special circumstances.

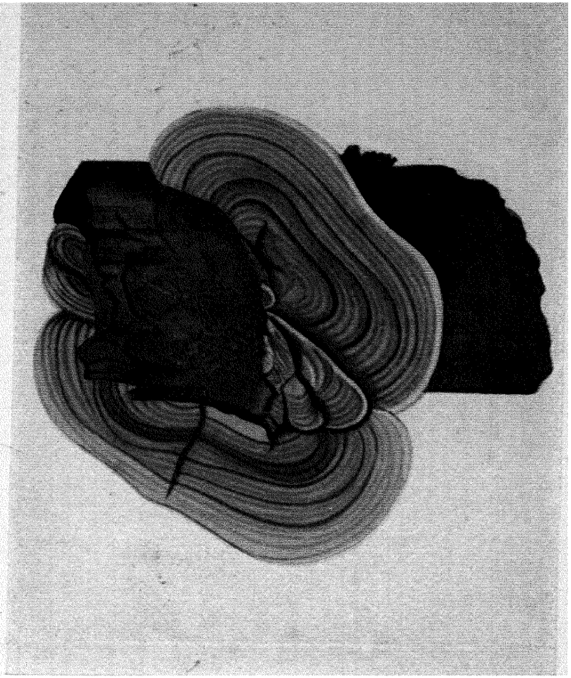
(3) Wounding of healthy trees around the collar during cultivation operations is not considered to be of any special significance in aiding the fungus to attack the root system.

Treatment of *F. lignosus* should be commenced by exposure of the root system, and if diseased roots are found, the source of infection must be found and extracted. Infected stumps should be removed as far as practicable. Soil surrounding diseased stumps or infected rubber trees should be dug over to a depth of eighteen inches and small fragments of jungle timber removed.



Ganoderma pseudoferreum

Fructification showing upper surface of single, common form, with distinctive, prominent, white edge.



Fomes lignosus

Showing zoned, orange-coloured, upper surface of fructification of *F. lignosus* in its freshest condition. It is seldom that field specimens showing such bright coloration are obtained. (About natural size.)

Rubber roots carrying rhizomorphs should be examined carefully to see if the fungus is in the epiphytic state, i.e. not penetrating the root tissues. This is done by carefully scraping the mycelium from the roots with some sharp instrument, and if there is no underlying discoloration in the cortical tissues, the root system is well drenched in a solution of 2 per cent copper sulphate, and roots which have carried any traces of the fungus are gently rubbed to remove all traces of the infection. Other materials beside copper sulphate have been used with successful results. If the underlying cortical tissue is found to show the slightest discoloration whatever, the root must be cut off, the cut being made in healthy tissue, while the healthy tissue exposed by the cut should be protected by the application of a wound cover such as tar or kerosene and asphaltum mixture. When this work has been completed, the earth should be replaced and packed down in its original position around the roots.

The writer fully appreciates that, during depressed financial periods, the advice given cannot be followed because of depleted finances. In such cases, some modification of the main routine will have to be undertaken or the disease must be left to take its course. Any modification which might be possible can only be discovered by the personal visit of an expert plant pathologist, and if expert advice is available, this should be obtained. It has already been shown that there are many dangers to be expected if the disease is allowed to take its course owing to lack of money or for any other reason.

GANODERMA PSEUDOFERREUM (WAKEF.), VAN. O. ET ST. (*Red-Root Disease*)

This particular disease was first reported upon in Malaya, in 1916, by Belgrave. The reason for the early names of *Poria* disease coupled with wet-root rot, later *Fomes pseudoferreus*, and at the present time *Ganoderma pseudoferreum* coupled with the common name, red-root disease, is detailed in an earlier section. In connection with the latter name it must again be mentioned that Petch describes in the 1921 edition of his book a red-root disease on rubber trees, caused by *Poria hypobrunnea*. This disease is quite distinct from that caused by *G. pseudoferreum*, and has not been found in Malaya, and according to Murray it is one of the most uncommon to which *Hevea* is prone in Ceylon. Red-root disease is very common in Malaya and is responsible for a large amount of damage in old rubber areas. It is found in Java and was first reported in 1920. Steinmann states that in western Java it is one of the most frequently occurring and most widely

distributed root diseases of *H. brasiliensis*, and that it would not be exaggerating to say that there is scarcely a single estate on which there are not at least a couple of trees that show infection by this fungus. In East Java the disease seems to be less general. According to official reports, the disease caused by *G. pseudoferreum* has not yet been found in Ceylon.

The following quotations may be given from Steinmann's book, after which points of difference, as seen in Malaya, may be appreciated more readily:

Red-root fungus occurs most frequently on heavy clay soils, on estates that have trouble with water in the sub-soil, in depressions in the land, in the vicinity of rivers, etc., and especially in old fields; this fact is connected with the progress of the disease. In the initial stages of the disease there are no outward signs. The trees continue to appear healthy and fresh; this is due to the fact that the infection as a rule is confined to one side of the root system. Outward signs only appear after a lapse of years; the tops die back, the crowns become sparse and the leaves wither and turn yellow. But during this time the fungus has had an opportunity of spreading all over the field and for preventive measures it is then too late. It may happen that fields that outwardly look healthy, in the end turn out to be completely infected with red-root fungus. It is the slow rate of spread of the disease which makes it more especially dangerous. The red-root fungus is often found with the white-root fungus together on the same root; confusion may then take place as the disease symptoms are then mixed.

In Malaya, red-root disease occurs commonly in mature areas on most types of soil and little can be said in respect of the fungus, showing preference for certain types of soil or any particular situation. On plantations possessing both hilly and flat land areas carrying mature rubber trees, serious root-disease losses may be met with in both types of land. In such cases it may be found that the losses on the flat land areas are due entirely to *Fomes lignosus*, while those on the hilly areas, over the same estate, will be found to be caused by *G. pseudoferreum*. On a neighbouring estate, the exact reverse situation may be encountered with *G. pseudoferreum* as the common cause of the losses on the flat land areas and *F. lignosus* predominating largely on the hilly areas. When both fungi are present in the circumstances indicated, the exact situation can never be predicted with certainty, but it is seldom that a mixed infection is found.

In 1917 Belgrave recorded that only one estate had had its young rubber badly attacked by *Poria*, and the death of isolated trees which had been attributed to *F. lignosus* or brown-root disease was really caused by *G. pseudoferreum*. But though this report was made so early, the true status of this fungus as a parasite on the roots of young

rubber trees was not fully realised until 1931–32. Belgrave's record of *G. pseudoferreum* attacking young trees was the only one up to November 1930, when E. von Zboray, in Java, reported that he had found true red-root disease on trees four to five years of age. A copy of this article is reproduced in a later section (page 202). All investigators had considered the typical attack, as seen on mature trees, to be of major importance.

This attitude can well be understood, for until recently there were two outstanding facts difficult of explanation, viz.: (*a*) that the disease, omitting the exceptional attacks found on young trees before 1930, seldom became prominent until trees were about ten to twelve years of age; (*b*) that most of the attacked trees were, or had been considered to be, good yielding trees.

Steinmann says, "It is especially the slowness of the progress of the disease which makes it so dangerous". This general statement has been accepted to account for (*a*), assuming that "slowness of growth" under the conditions prevailing was an inherent quality of the fungus. The fungus undoubtedly develops comparatively much more slowly than *F. lignosus* in time, but this fact does not allow for a complete explanation.

In 1931, while supervising a trenching system in a badly infected area, the number of diseased roots which showed the proliferation of large masses of adventitious roots was very noticeable (Fig. 19).

Fig. 19 shows the typical appearance of diseased roots with adventitious roots springing from them. In one it is obvious that the rubber root has recovered naturally as the result of the adventitious root development, for further penetration of the fungus has been prevented successfully.

The prolific production of adventitious roots on attacked trees led to a natural conclusion which has proved to be correct. The assumption that the production of healthy, absorbing, adventitious roots is a common reaction to the attacks of *G. pseudoferreum* led to the conclusion that the absorptive area of the root system would be increased substantially, and the general physiological reaction to the fungus attacks would be the absorption of an increased supply of water and food materials in solution. Further, the rate of the progress of the fungus through attacked root tissues would be considerably retarded when the general vigour of the plant is maintained at a normal level, because adequate supplies of food materials are available owing to the development of a copious supply of adventitious roots.

Thus, if trees are attacked in the earliest stages of the plantation,

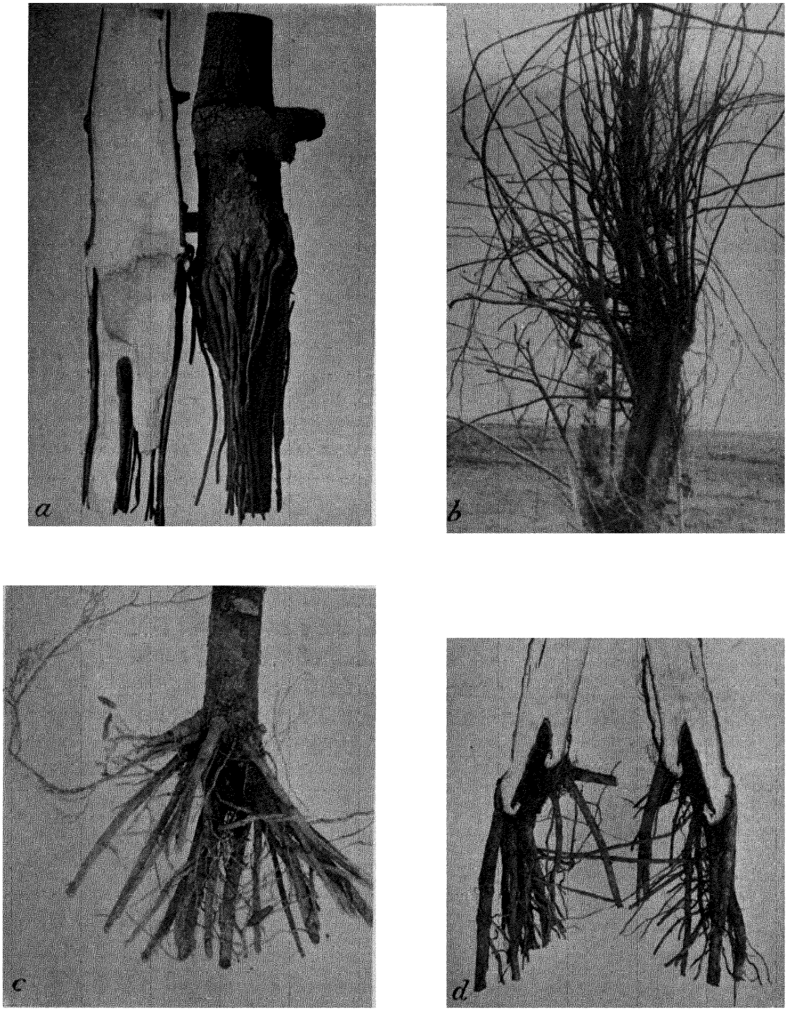


FIG. 19.—*Ganoderma pseudoferreum*. Illustrations showing proliferation of adventitious roots from roots of rubber trees severely attacked.

a, Attack on tap-root of young tree. Note ring of adventitious roots produced at region of collar, growing vertically, straight downwards, into soil.
b, Surface, lateral root of old tree showing common appearance, with extensive development of adventitious roots.
c, Affected lateral root of old tree.
d, Showing root in *c*, split open. The fungus attack has been entirely checked, and the diseased wood cut out thoroughly, by the development of the ring of healthy adventitious roots.

there is no reason to expect external symptoms in the crown to appear at once, for the response of the attacked plant is the production of numerous adventitious roots from the unaffected root tissue, and these readily absorb water and food materials. As the disease remains entirely subterranean, only trees of mature age, not less than ten years old, are likely to be found showing typical symptoms. But it is perfectly plain on this reasoning that *G. pseudoferreum* will be present on rubber trees much younger than the age mentioned, and that it might be found in the earliest stages of the plantation.

The above would also provide a probable explanation for the assertion often made by planters, that their best yielding trees are always the first to be found attacked by red-root disease. The profuse proliferation of healthy adventitious roots, capable of water absorption, would result in increased absorption of water and nutrient solutions, and increased yields of latex may be expected to follow naturally.

It is now fully established in Malaya that *G. pseudoferreum* is present in the earliest stages of the plantations. A diligent search resulted in the disease being found on trees four to five years of age (Fig. 20 *a* and *b*). Subsequently trees not more than three years of age were found attacked by the fungus, and more recently still Napper has shown that the "knots" of disease are very well defined and compact, and that diseased trees can be found at the same time as the first cases of *Fomes lignosus*, when the plantation is carrying trees not more than one and a half to two and a half years of age. There is no doubt that large numbers of young trees which have developed diseased roots have been diagnosed as *F. lignosus* in the past, whereas the proper diagnosis should have been *G. pseudoferreum*.

Symptoms.—In mature trees, the woody tissues of attacked roots degenerate into a soft, spongy mass from which water can be squeezed under the pressure of the fingers. This "wetness" of diseased wood is independent of situation, but is not very obvious in young plants. In addition to the wetness of diseased tissues, attacked roots are characterised by the formation of red rhizomorphs on the external surface. These rhizomorphs are formed from simple, red, mycelial strands which later fuse together to form a continuous membrane. The rhizomorphic membrane and individual rhizomorphs are not always easily seen when first extracted from the ground, as portions of the soil remain attached, being held by the rhizomorphs; it is therefore necessary to wash the soil away before the red rhizomorphs and membranes can be recognised. In diagnosing the disease on young trees, the only reliable guide is the presence of red mycelial strands or

membranes. When the strands and membranes are young they are light red; when drying the red colour fades to a dirty white, but the colour reappears after moistening. When older, the colour is deep claret and remains unchanged by drying. When the roots are entirely rotten, the colour of the rhizomorphic membranes approaches a blackish violet colour and single, separated rhizomorphs are found only occasionally (Plate I).

The production of a complete, external skin of fungus tissue by the union of blood-red rhizomorphs appears to be a constant feature of a certain phase. This external skin is never found on the upper parts of diseased lateral roots exposed to light and air, though it may be found occasionally on the under-side of such surface roots, which are in contact with or slightly buried in the soil.

The progress of the disease in surface roots is always more marked along the under-side; the lower surface in contact with the soil may be completely rotted, while the upper half remains free from attack. In roots which have the upper surface exposed to the atmosphere, the line between healthy and diseased tissues is well marked even externally. This is caused by the development of a well-marked line of "callus growth" from the healthy tissues on the upper surface. In vigorous trees, the callus development may proceed so far as to completely occlude the diseased woody tissue, and in some cases the fungus is prevented from penetrating further along the root by this means. The common response shown by attacked roots is a profuse proliferation of adventitious roots, and this is a striking feature in mature trees. But even in young trees, which show roots attacked by this fungus, the proliferation of adventitious roots is pronounced and appears often as a sort of digitate branching, as shown in Fig. 20 *a* and *b*.

The young, diseased root illustrated was split open longitudinally in the laboratory on the day it was extracted from the soil. When it was split open, only a small portion of the under-side of the root, the portion marked (*a*), showed the typical dark brown colour of red-root rot (Fig. 20 *a* and *b*). The split root was left exposed to the air for a few days when the portion marked (*b*) was found discolouring; first, from a white healthy-looking state to a light brown colour, which later became darker brown, and on the third day after splitting no further discoloration took place. This portion of the wood, which appeared quite healthy when split, never attained the dark brown colour of the wood obviously diseased at the time of splitting. However, when examined microscopically, the hyphae of the fungus could be made out quite easily and they were present in plenty. The subject is not

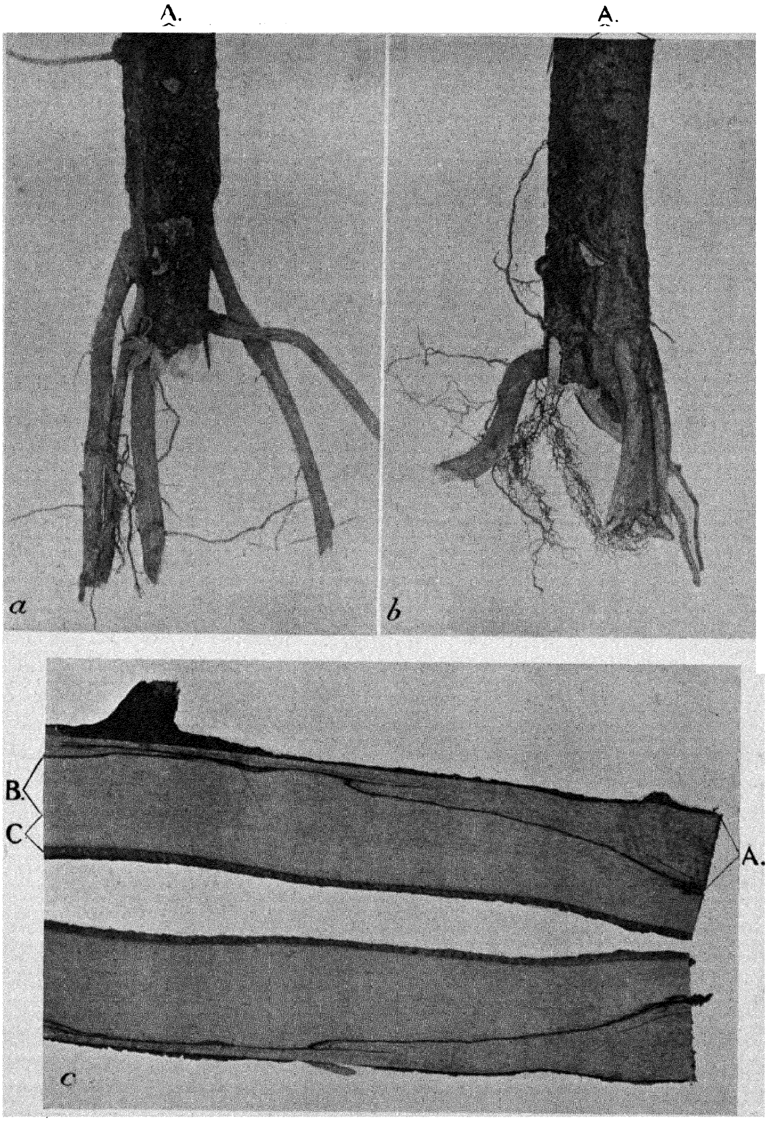


FIG. 20.—Photographs illustrating first case of roots of young rubber tree found attacked by *G. pseudoferreum*.

The specimen illustrated was found on a tree 3½ years of age; it was 9 inches below soil level and the diseased tissue in the root was confined to the under surface. Note apparent digitate branching, due to proliferation of healthy roots from healthy tissue on upper surface.

a, Region of root marked A indicates diseased under surface.
b, Region of root marked A shows healthy upper surface, from which adventitious roots spring.
c, Same root as in *a* and *b*, split open. A = badly diseased under surface. B = slightly diseased area, with discoloured wood not very prominent in photograph. C = healthy tissue on upper surface.

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one of special importance and may be left without further comment. Should any investigator desire to obtain the details in respect of the investigation of diseased tissues, the article by Belgrave should be consulted.

In addition to the main symptoms already described here, Belgrave also draws attention to the following minor details:

(*h*) The presence of brown, not black, lines in the wood. The lines are very thin and sharply defined, and as a rule run nearly straight, without the reticulation characteristic of the lines of *Ustulina*. They sometimes curve to enclose small islands, which are more decayed than the surrounding wood. The lines are really the edges of plates of hard brown tissue seen in section.

(*i*) The presence of discoloured light brown areas in the wood. Such areas usually occur near the junction of healthy with diseased tissue, and are often limited on the healthy side by a distinct, darker brown band (cf. with description of split root given above).

(*j*) Honeycombing of the wood of *Hevea* roots, though rare, is sometimes seen, and is frequently, though not invariably, due to *F. pseudoferreus* (*G. pseudoferreum*). Such honeycombing is of common occurrence on jungle wood.

As will be seen later, Petch and Murray, working in Ceylon, call attention to the above features described by Belgrave for *G. pseudoferreum*, but they are described in connection with root tissues affected by brown-root disease. Numerous, thin brown lines are easy to see in cases of typical brown-root disease in Malaya, and they conform to the above description. Honeycombing of the wood of *Hevea* roots is also ascribed to brown-root disease in Ceylon.

The woody elements of attacked roots may finally become so completely disintegrated that diseased roots resemble "mummified" roots. These pseudo-roots have dried out, and are composed of a well-developed, external "red-skin" surrounding an aggregated mass of fungus tissue, which simulates a false, parenchymatous tissue. None, or very few woody elements, can be found in the pseudo-roots by the use of the usual wood stains.

When diseased roots showing the later stages of red-root disease are opened up and exposed to the atmosphere, the decaying mass is found to be already invaded by many species of non-pathogenic fungi. After twenty-four hours of exposure the decayed roots are often covered with a brilliant blue-green *Penicillium* species. In other cases diseased roots are, at certain periods, often grown over externally with a thick white fungus cover, often half an inch thick. This fungus is *Echinodia theobromae*, Pat., and is characterised by the fact that the

surface, if examined, will be found to be covered with upright outgrowths resembling small teeth, upon which the spores are borne.

Fructifications.—Both in Java and Malaya, a considerable period of time elapsed before the fructifications of *G. pseudoferreum* were definitely recognised on rubber trees. Corner took up the question of the identity of Javan and Malayan specimens of this fungus in 1931,

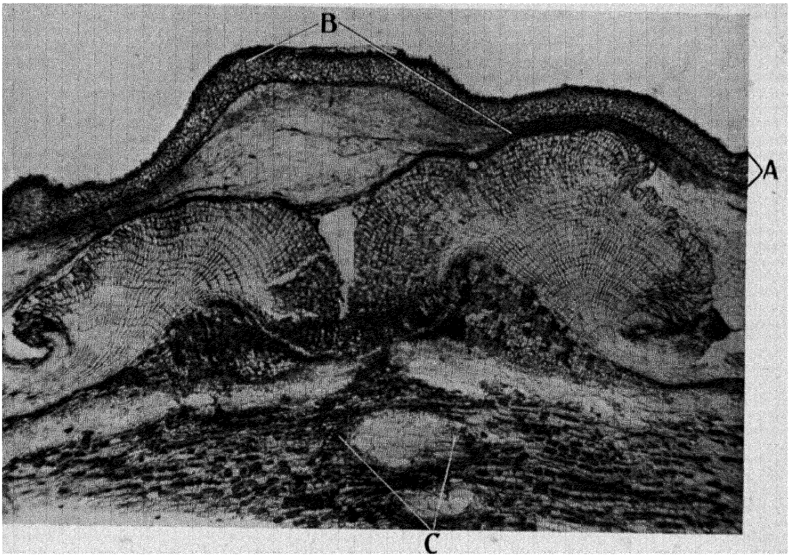

FIG. 21.—Transverse section through root badly attacked by *G. pseudoferreum*, though not in the final state of disintegration.

A = Showing structure of external rhizomorphic membrane.
B = Mass of filamentous fungus tissue beneath the external membrane, without definite cellular form.
C = Similar masses of filamentous fungus tissue as in B, but placed much deeper.

Between B and C are distinct, cellular tissue developments, fan-shaped in appearance. These are offshoots of root tissue in rapid division, as shown by the radial distribution of the cells of which they are composed. This represents an attempt to cut out the fungus tissues external to these developing fan-shaped portions of root tissue. But the fungus has penetrated well below this level, as shown by the clumps of fungus tissue marked C.

and as a result of his examination of the fungus from both countries, he concluded that they were alike in every respect, and that the name must be *Ganoderma pseudoferreum* (Wakef.), Van O. et St.

Corner reports this species as common on dead stumps in the Singapore Botanic Gardens and also in the lowland forest of Malaya. He has found it parasitic at the base of several large trees in the forest in Johore and Pahang, and has found the fructifications on *Myristica* sp., *Pterocarpus* sp. and *Arenga saccharifera* in Singapore. Van

Overeem records *Metroxylon* sp., *Albizzia* sp. and *Durio zibethinus* (Durian) as other hosts on which the fungus is parasitic.

In his 1925 edition Steinmann remarks:

Up till recently the fruit-bodies of *G. pseudoferreum* were practically unknown on our rubber estates, and the reason for this was that the fruit-bodies appear only at a late stage of development, when the vegetative mycelium has in most cases already rotted away; it may also be due to premature blowing-down of diseased trees. This also explains why fruit-bodies are seldom seen on those estates where diseased trees are treated immediately after discovery.

In Malaya the fructifications have recently been found developing freely on old logs of diseased rubber trees which had been felled and allowed to remain *in situ* for a considerable time.

The fructifications develop occasionally at the base of diseased trees which are still standing. They are commonly found developing on the bole of the tree at ground-level, between two large lateral roots. The fructifications, in the early stages, appear as a round or spherical knob-like proliferation, which is usually known as the "primordial knob", and may be 1–2 ins. in diameter. At the slightest touch, yellow or brown spots appear. The basal part, during further development, turns grey and brown and finally brownish-black, while the crust becomes more or less smooth. The white, spherical, primordial knob now starts growing out into a hood. Sometimes it widens, but little or no growth in width may take place at the base; in such cases, a distinct stalk is formed. Usually, however, there is no definite stalk formed and the fructifications are sessile, but abnormal cases have been recorded of stalk and fruit-body with a total length of 12 ins. approximately, the length of the stalk being about 7½ ins. Plate II and Figs. 22 and 23 are illustrations of the fructifications.

During the development of the bracket or pileus from the primordial knob, the under surface remains completely white and small shallow pores develop. In most cases the brackets develop singly but compound fructifications are quite commonly met with. These compound fructifications closely resemble those of *Ganoderma applanatum* (Fig. 23). Corner's remarks, that *G. pseudoferreum* comes very close to *G. applanatum* and that it may prove to be a variety, have already been noted.

The following unpublished report by Napper is of interest in connection with the development of fructifications and spores in Malaya. To make the information complete, the full description of mature fructifications is later taken from Corner's article, which may not be readily available to other investigators.

FIG. 22.—Fructifications of *G. pseudoferreum* developing at base of old infected rubber tree.

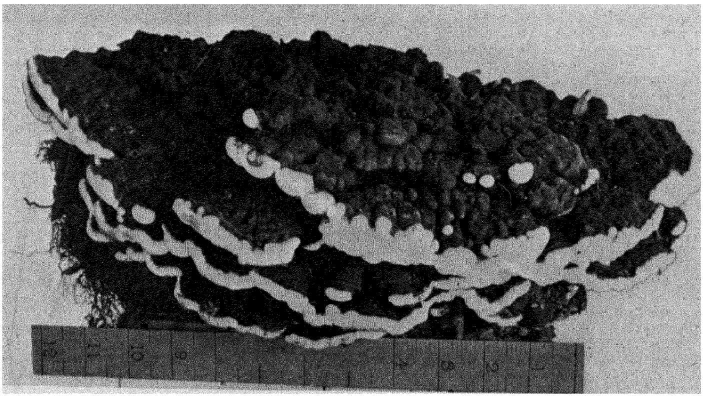

FIG. 23.—*Ganoderma pseudoferreum.* Imbricate form of fructification, resembling that of *G. applanatum.* (From *Quart. Jour. Rubber Research of Malaya.*)

Napper made observations on the fructifications of *G. pseudoferreum* on an estate where for some five years little was done towards destroying the root systems of trees which had become casualties owing to attacks by the fungus. Trees were felled when they died and the boles extracted and

allowed to rot *in situ*. During the latter half of March [1933], immature fruit-bodies of *G. pseudoferreum* were seen on a few of these rotting boles, and their development was watched closely. During April, young fruits were seen more frequently, and at the beginning of May, a general fruiting season had commenced all over the property. By the middle of the month nearly every old diseased bole bore its quota of fruit-bodies. Up to May 24th, all fructifications seen conformed to a definite and unmistakable pattern. They were dead white on the under-side, with a conspicuous edge of the same hue, while the upper surface was dully lacquered, and zoned in shades of dark tawny brown, merging into black. On the above date, a new type was seen, which at first sight appeared to belong to a different fungus altogether. The pore surface was the same white colour, but the edge was brown instead of white, and the upper surface was a uniform dull, light brown in colour instead of being lacquered and zoned in shades of dark brown. In fact, the fruit-bodies looked as though they had been generally sprinkled with cocoa powder. The analogy is a good one, for, on examination, the deposit was found to consist entirely of spores. On scraping or washing the surface the dark zoned appearance was regenerated. This new type was found to represent the stage in development at which growth had stopped (no white edge), and the profuse sporing phase has begun. The rate of deposition of spores was very rapid. Glass slides placed beneath the fruits for an hour were found on removal to carry a heavy deposit of spores. In one extreme instance, the deposit was plainly visible as a brown film on the slides. Similar attempts to obtain spore deposits from the younger fruit-bodies had met with very disappointing results, although microscopic examination showed that spore development was progressing rapidly.

The spores are golden brown in colour, elliptical to egg-shaped, $6–8\mu \times 4–5\mu$, borne in a pendulous manner from long sterigmata. The point of attachment to the sterigma is at the smaller end, this being the part remotest from the hymenium. The basidia are colourless, above 14μ high by 10μ broad, each bearing four sterigmata in the form of a crown. The long axes of the spores are slightly inclined outwards from the normal to the surface of the hymenium, making it appear as though the basidia are rotating slowly about an axis perpendicular to the hymenium (cf. governor balls).

The spores are thick-walled and possess a remarkable capacity for withstanding desiccation. Fifty per cent germination was obtained from the spore deposit on the surface of one of the fruits. This fruit was the highest bracket on a prostrate bole (being about two feet from the ground), and the spores on its surface must have floated up from below after a lengthy journey through the air. Some of the spores which germinated must have been exposed for more than 24 hours to the drying action of sun and wind. The rapidity of deposition, purity and vigour of germination of this spore deposit, can be judged by the fact that the cultures obtained by smearing the tip of a wet brush over the surface of the fruit-body and then over corn-meal agar in a Petri dish, remained pure long enough to enable an isolation of *G. pseudoferreum* to be made.

Strong evidence was also obtained that the spores *need* a considerable amount of desiccation before they will germinate. Although such free germination was obtained from the well-dried spores on the surface of the fruit-body, no germination was obtained from spores deposited in a closed damp chamber, or on slides exposed for a short period of time in the field. Spores deposited in an open dry chamber had germinated, however, on the dry surface of the slides after 24 hours. A more precise determination of the limits of desiccation between which germination is possible will be made.

The main points of practical interest which arose from the observations were:

(*a*) Fructifications of *G. pseudoferreum* on rubber trees are rarities in this country [Malaya], merely because infected wood is usually destroyed before it reaches the stage of rotting at which the formation of fruiting structures begins. This stage is reached after three or four years exposure in the field. Fruiting is particularly favoured by long periods of wet weather, such as we have recently experienced, and continues intermittently over many years, for the older rotting boles bear the disintegrating skeletons of several previous batches of fructifications. In a normal year in Malaya, there are probably two fruiting seasons, viz. April–June and October–December respectively.

(*b*) The mature fructifications bear viable spores in great abundance, and the spores can withstand a high degree of desiccation.

There is nothing therefore in the mechanism of spore development and dispersal in *G. pseudoferreum* which could inhibit the free spread of red-root disease by means of spores. It will be necessary to determine whether such spread actually takes place in plantations, as if it does, the destruction of fruit-bodies will become a vital part of any control scheme.

From previous experience, however, it is probable that fruit destruction will not be necessary. No diseased tree has yet been seen whose infection could not be traced to root contact with buried infected timber, and further, the mode of origin and spread of red-root disease in a stand of rubber is typical of a purely vegetative means of propagation. Some factors connected with germination and infection probably operate to preclude successful spore infection in the field.

The most likely factors are:

(1) Sensitivity to competition, which would tend to inhibit (*a*) the establishment of the fungus as a pure saprophyte in the soil, (*b*) the colonisation of wounds and (*c*) the infection and colonisation of exposed stumps.

(2) Inability of the spores to produce germ-tubes sufficiently long and vigorous to effect direct penetration of healthy bark. Even penetration hyphae developing from the under-surface of rhizomorphs are unable to do this when their vigour of growth is insufficient to break through the defences of the host.

The full description following is taken from the article by Corner:

The fructifications may be sessile or only short stalked. This is the most common type. They may be flattened out, horizontal or ascending, often

overlapping as the tiles of a roof, up to 21 cm. in radius and 31 cm. wide.

The upper surface is smooth or covered with a velvety coating of fine soft hairs, rather dull, with small grooves, often with irregular excrescences on the surface. The colour of the upper surface is fuscous-amber, or blackish with crowded cinnamon, brownish-olivaceous or khaki-coloured, narrow wavy zones and with a conspicuous bright, chestnut-brown, sub-resinaceous zone (2–10 mm. wide) near the margin; eventually dull brown from deposited spores. Margin white, thick and tumid at first, becoming thin, sub-acute, and often lobed or proliferating small pilei.

Stem, when present, sub-cylindric or flattened, expanding gradually into the pileus, up to 6 cm. long × 1·5–8·5 cm. wide, the same colour as the upper surface of the pileus. If a radial section from the point of attachment to the margin of the pileus is taken, it will be found that the flesh of the pileus varies from 16–45 mm. thick at the base (point of attachment), relatively thin in the mature pilei (5–10 mm.), at half-way to the margin, cinnamon hay-brown in colour, and darker over the pores, mostly very pale near the upper surface, darkening with age, with narrow, alternating dark and light zones, developing thin fuscous or blackish crustaceous lines, 0·2–1 mm. thick from the base to the margin, with a thin blackish crust 0·2–0·5 mm. thick on the upper side.

The pores or tubes, the openings of which are seen on the under surface, are up to 10 mm. long at the base, fuscous or blackish brown, drying to the same colour as the flesh; pores white, small, circular, entire, 100–150μ wide, with dissepiments 40–100μ thick.

Spores, dark ferruginous when seen in mass, ellipsoid, sub-truncate at one end appearing minutely echinulate, 6–7·5μ × 4·5–5μ, with one large gutta, 1·5–2·5μ wide.

Smell strong, like mice and cheese when kept for a few days.

The pale-coloured flesh in the upper half of the pileus appears to be as characteristic as the variously coloured zones on the surface, but both features disappear with age. The zones are ultimately obscured by the thick deposit of spores which settle on the pilei, and the flesh darkens in colour as the crustaceous lines develop centrifugally. The upper side is not shining or laccate, as in *G. lucidium*, though the chestnut-coloured zone near the margin is sometimes sticky and sub-resinaceous.

The thickness of the flesh varies considerably according to the size of the primordia, but well-developed pilei are always relatively thin and never become hoof-shaped.

The growth of the fruit-bodies appears to be rather slow, at least three or four months being required for the pilei to reach a size of 12–15 cm. Sporing begins at a late stage, not until the pilei are 5–15 cm. in radius, and the tubes are 3–8 mm. long. (Steinmann says basidia and spores are rather hard to find and in younger stages are usually searched for in vain. However, at the right time, when conditions are favourable, thick deposits of spores are formed, and in the compound fructifications the upper surfaces of the pilei situated in the lower positions are covered with a thick layer of spores which change the colour of the upper surface.)

Fruit-bodies which have developed in open situations often assume irregular shapes, since their growth is interrupted by spells of dry weather; they consist of the original primordial knob, 1–6 cm. in diameter, at the end of which other knobs, lobes or rudimentary pilei have developed with or without intervening short layers of tubes. These abortive specimens are seldom fertile, but they can be identified from the characteristic colouring. They are the forms most likely to be met with on rubber estates.

The fruit-bodies always develop low down near the base of infected trees or from the roots, and similarly on dead stumps. Those of *G. applanatum*, on the other hand, may develop from a considerable height, up to 20 feet or more above the ground.

The same explanation is given by both Steinmann and Napper for the rare occurrence of fructifications of *G. pseudoferreum* on diseased rubber trees in Java and Malaya.

Corner's and Napper's descriptions in general tally with one another very closely, though the former's is given in much more detailed form.

Control and Treatment.—The writer hopes that it has been made clear that the control of the root diseases caused by species of the *Fomes* type is a broad general problem confronting the rubber cultivator. *Ganoderma pseudoferreum* is present from the opening-up of the plantations (a feature long recognised in the case of *F. lignosus*), and the early tree-to-tree inspection and systematic removal of infected jungle timber, recommended for the control of *F. lignosus*, is as important, and probably more so, for successful control of *G. pseudoferreum* in later years.

For areas of young rubber, the plan of campaign for controlling the spread of *G. pseudoferreum* in the plantations has been set out in the form of recommendations given for treatment of *F. lignosus*. But while the latter has reached its peak about the 4th–5th year and the percentage infection is on the wane, the same cannot be said of *G. pseudoferreum*, for, unless special attention is given to the diseased patches to be found in earlier years, the disease caused by this fungus attains greater prominence year by year after the trees are ten years of age. It has already been indicated that a system of trenching will become of full utility in mature areas, but if these have received the early treatment recommended, diseased areas which require trenching should be small in both extent and number, and as a consequence the expenditure required would be comparatively small.

The condition of diseased areas will definitely determine the treatment to be recommended in the matter of trenching. On areas with trees twenty to twenty-five years of age, where the disease has been rampant for years, no economic system of trenching could be recom-

mended; the only undertaking which would meet the case would be replanting. On areas with trees ten to fifteen years of age, where little attention has been paid to treatment in the early stages, a system of trenching, which is rather expensive, can be undertaken. Whether this would prove to be an economic success would depend entirely on the price of the commodity. A trenching scheme has been worked upon by one estate in Selangor and complete details have been pub-

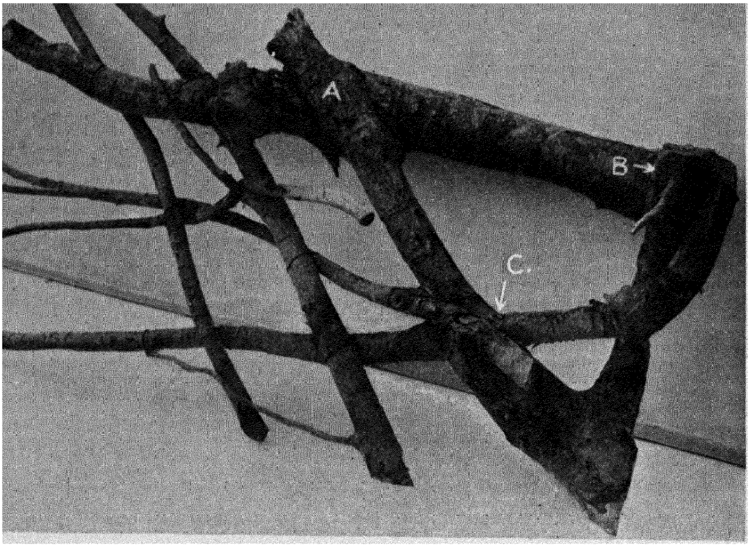

FIG. 24.—*Ganoderma pseudoferreum*. Dissection of soil area in field of old rubber, size 5 feet by 4 feet.

Roots of five different trees are in contact in this small area and all have contracted the disease from the one tree which became diseased originally. Root grafts have been formed at A, B and C.

lished; these are given later. It is sufficient to say at this stage that the results were considered satisfactory, probably because only a single diseased tree has been found during ten years in the treated area of over forty-six acres.

The progress of the disease in attacked roots is practically entirely subterranean; the underground habit of the fungus makes it a greater menace than it would be otherwise. The method of spread is entirely by root-contact, even though fructifications and spores may be produced profusely. This bald statement gives but little idea of the extremely slow and intricate nature of the root systems of the trees in a field of twenty-year-old rubber.

Fig. 24 shows the roots of five trees crossing in a soil area covering only five feet by four feet; they are in such close contact that root grafts have developed between three of the trees. The formation of root grafts was found to be quite a common development in this badly diseased area. At first there was only one tree with a diseased root; at a later date the roots of the other four trees contracted the disease from this one. In another case, a diseased root was traced to a distance of forty-five feet away from the stem, and this one infected the roots of five other trees with which it came in contact.

The investigator who first studied red-root disease intensively in Malaya was Belgrave. He detailed his findings in a special bulletin issued by the Department of Agriculture, Federated Malay States, in 1919. This bulletin is now out of print and it is difficult to obtain a copy, but in order to show the unanimous opinion of all Malayan investigators, more especially with regard to the method of spread of the disease from tree to tree by root-contact (cf. *Rhizoctonia bataticola*), it will be advantageous to give a short extract from the work at this point:

Large numbers of similar cases have since been found, abundantly proving the spread of the fungus under plantation conditions to be by contact of the roots, either with the diseased roots or stumps of jungle trees, or with other diseased *Hevea* roots. *F. pseudo-ferreus* has been found to attack all kinds of jungle woods, both hard and soft, white and red, being in fact, especially in early stages, one of the normal fungi causing decay of jungle timber in Malaya; hence no system of selective clearing can be devised to afford protection to *Hevea.*

All the symptoms of an attack of the fungus so far described have referred to parts of the plant normally invisible, viz. roots and lower part of the collar; opening up is necessary to find the disease while the tree is yet standing. Added to this invisibility, shared with all root diseases, *F. pseudo-ferreus* has a slowness of advance into healthy tissues peculiarly its own, with the result that a tree may be badly diseased for many years without showing it. The persistence of diseased trees is aided by the partiality of the fungus for "heart-wood" which has ceased to function in water conduction, and by the fact that the attacks are as a rule confined for a long time to one side of the collar. As a result, the water supply is not sufficiently reduced to cause general wilting. There is one sign, however, by which badly attacked trees may often be discovered, viz. the occurrence of bare tips (usually on the highest branch), looking like slight attacks of "die-back". When such tips are seen, at a season which excludes wintering, and the "die-back" does not spread, *F. pseudo-ferreus* may be suspected, and the tree opened up.

As an instance of the elusiveness of *F. pseudo-ferreus* may be taken the Government Plantation at Kuala Lumpur, where the 17-year-old rubber has been found to have about 30 per cent of trees attacked; and this was

only accidentally discovered when a tree-to-tree examination (for other purposes) was in progress.

In fields of old rubber which have received little attention from the point of view of root-disease treatment, the total disease percentage can never be guessed correctly without full disclosure of the root system. In a field with groups of trees which are obviously affected and require extraction, there will be a high percentage which are lightly attacked, the diseased tissues being still confined to the lateral root system. In one case already mentioned, the total disease percentage was 56; of this total 26 per cent were obvious cases for extraction, the fungus having reached and penetrated into the tissues of the bole of the tree; 30 per cent were lightly affected cases which could be saved by excision of diseased lateral roots. This vital point has to be kept in mind when considering treatment. The number of obvious cases may reach a high percentage of the total stand, but it is probable that there is a higher percentage of lightly affected cases still left in the ground.

The progress of the disease in old neglected areas is well shown in Diagram V. The disease spreads in ever-widening circles, those marked A–K representing typical diseased patches where the fungus has been active and allowed full play. As the direct result of the removal of a large number of diseased trees, a serious decline in yield ensues, and ultimately it may become unprofitable to tap those which remain.

In a special bulletin published in 1931, before sufficient evidence had been collected definitely to conclude that *G. pseudoferreum* must be accepted as a root parasite of jungle trees (falling in the same category as *F. lignosus* and therefore likely to be found on young rubber trees equally early), the writer recommended a system of trenching on mature rubber estates, assuming that individual cases of root disease caused by *G. pseudoferreum* might be found when the trees were about the tenth year of age. As further experience has been gained, it is obvious that the single system of trenching described below will satisfy all cases, and the above-mentioned system must now be discarded.

Trenching has been recommended for treatment of root diseases of rubber from the earliest days of the industry, but judging from the present-day position, trenching systems have been used with but doubtful success. This is not because of any inherent defect in the method, but because it has been carried out in ignorance of the true state of affairs existing below the surface of the soil. It is useless to try to guess where a trench should be made by looking at the foliage of

the trees at the edge of a diseased patch. Trees infected by *G. pseudoferreum* may linger on for years before they show signs of the disease in the foliage, and by the time they do so the advancing rhizomorphs

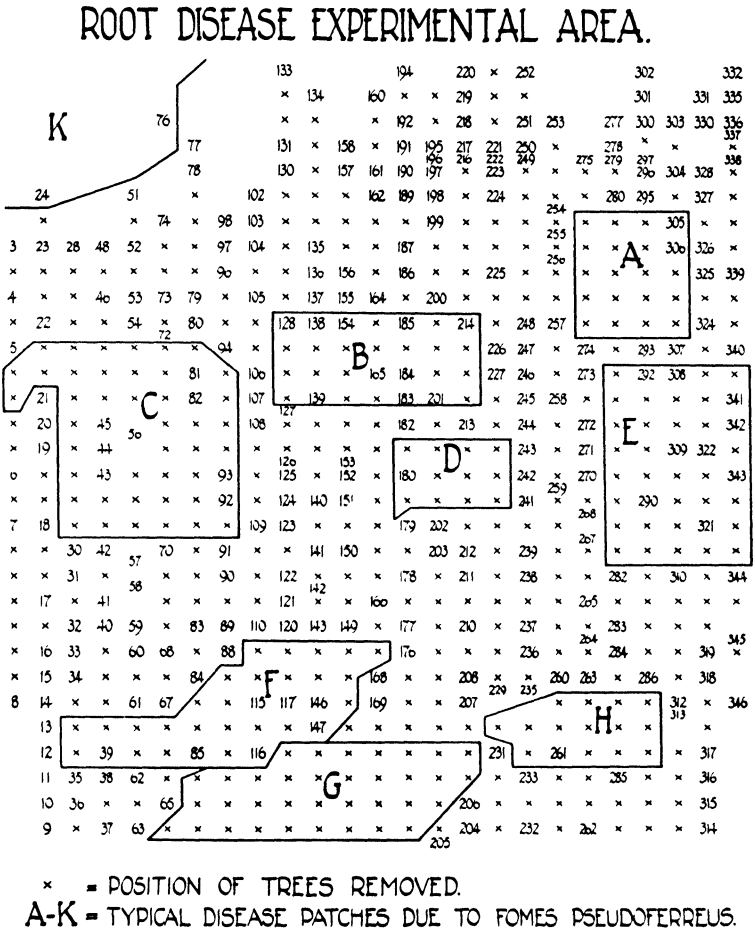

DIAGRAM V.

will have travelled ahead at least one, sometimes two, three or even more rows of trees, all of which may appear healthy. Neither the size nor even the shape of the true patch of infection can be judged by visual inspection, and no trench can be expected to be satisfactory unless it is dug in conjunction with a method of root inspection.

The necessary root inspection is carried out in quite a simple way. The main requirement of an isolation trench is that it shall be cut outside the advancing limits of the patch. If, therefore, in cutting the trench all the roots severed are healthy, the trench must be fulfilling this requirement. If, however, diseased roots are encountered, the trench is known to be incorrectly placed, and must now be taken in a direction which will include the tree showing the diseased roots, within the trenched area. The diseased roots are the indicators for the location of the trenches, and these must be taken further and further away from the diseased patch until all roots severed are healthy.

Near the advancing edges of a diseased patch, the rhizomorphs are in their freshest, most vigorous and most easily recognisable condition. It would be difficult to overlook a root rotted by this fungus, for when cut it will not yield any latex, while of the roots which do yield latex, the infected ones carry on their surface fresh, vigorous rhizomorphs which cannot possibly be mistaken for the clean surface of a healthy root. It is well to have a bucket of water handy where this work is being carried out, for the soil usually adheres closely to infected roots, and this must be washed away, when the rich red colour of the rhizomorphic membranes will be seen in the form of a tough skin covering the surface of the bark and easily detachable from it.

In isolating a diseased area, the trench should be dug in such a way that at least one row of standing trees comes between the trench and the denuded central portion. As the trench progresses round the patch, all severed root sections must be examined and, where diseased roots are found, the trench must be extended outwards to include other trees from the next row as required. Since it is necessary that the trench should be deep enough to sever all lateral roots crossing its line of progress, it should be dug midway between the rows of trees, as here the depth of penetration of the roots is at a minimum.

The cut ends of healthy roots which are severed during the progress of the trench should be covered with Asphaltum-Kerosene mixture.

No attempt should be made to confine the trenching system to a rigid geometrical pattern. The trench will wander through the trees in a somewhat crazy fashion, including trees here and there as they are found diseased. The trenches should be at least two feet deep, but it would be safer to aim at a depth of three feet. They should be inspected periodically and should be always kept open.

Treatment of the trees in the isolated areas can be decided on the spot. As there is little chance of spread by wind-blown spores, tapping

can be continued on any trees producing a fair yield of latex. In the writer's opinion, the trees within the isolated areas should be tapped as heavily as possible and, when the yield falls off owing to the progress of the disease in the tissues, they should be taken out. The tap-root should be removed completely to three feet below ground-level, and all diseased lateral roots should be followed up, taken out of the ground and destroyed, if possible by burning.

There is an obvious danger in the method recommended, and this lies in the wholesale cutting of lateral roots, which will possibly result in an increase in the number of cases of *Ustulina zonata*. This disease, however, can be dealt with comparatively easily and there should be little danger if the cut ends are treated quickly and then covered by the soil.

The above method, with modifications according to local conditions, can be put in operation on most estates, irrespective of their location or of the type of soil. It can be said to be of fairly general application. The important point is that the scheme demands an exceedingly careful examination of the lateral roots which are cut through when digging the trench.

Careful costings in relation to the method recommended above have been made on one estate in Selangor and, though expensive, the results obtained justify the expense, so that these measures enter the realm of practical politics. Up to date, our knowledge of root-disease treatment has been largely empirical; there has been no index by which the success or failure of the remedial operations could be gauged. In this connection, the number of trees in the first row outside the trench, which are found with diseased lateral roots, provides a definite indication of the results to be obtained by treatment. Excision of slightly infected lateral roots not only saves a valuable tree, but removes a definite and serious danger, as such trees left untreated would become in a few years centres of infection. The cost details are given below:

(1) Area of field treated	= 46 acres
(2) Total cost of disease treatment	= \$155·09
(3) Cost per acre over whole field	= \$3·40 (app.)
(4) Approximate ratio of diseased area to area of the whole field is 8·7 per cent (say 10 per cent)	= 4·6 acres
(5) Cost of treatment over 4–5 acres	= \$31·20–\$39·00 per acre
(6) Percentage number of diseased trees found in first row of trees outside the trench (treated and saved by severance of lateral roots), in total number of trees opened up	= 14·3 per cent

The fact that 14·3 per cent of the total number of trees opened up are in the first row, are found lightly affected and can be saved by excision of the diseased roots, forms a primary consideration when making recommendations for control. If such a high percentage should be found in the majority of cases, this alone would justify a recommendation in areas known to carry mature trees suffering from *Ganoderma pseudoferreum* that trenching operations should be undertaken as early as possible.

Soil treatment is as usual. The trench should be at least two to three feet deep and one foot wide, and the soil from the trench must be thrown on the ground inside the area bounded by the trench. When the diseased trees have been completely removed, the whole of the soil in the isolated area must be dug over to a depth of twelve to eighteen inches and, as far as possible, all rotting vegetable material should be collected and burnt.

It will be fully appreciated that costs of trenching will vary considerably according to soil type and situation. The costs given above were obtained by working typical laterite soil on slightly undulating ground. The work was carried out in 1931, and since that time only a single case of *G. pseudoferreum* has been found, and it is possible that this was a case of a lightly affected tree missed during the trenching operation.

The particular case published refers to an area in which the disease had been allowed to develop for a considerable time before a systematic attempt was made to deal with the situation, and, from a pathological point of view, was completely successful. Whether it will ultimately prove to be an economic success there is reason to doubt, but even from this point of view the results are so far considered to be satisfactory. But if the full combined scheme for *F. lignosus* and *G. pseudoferreum* is carried through from the early years when the former first becomes prominent on the young rubber trees, there is no reason left for doubting the economic outcome.

FOMES NOXIUS, SP. N.
(*Brown-Root Disease*)

Up to 1917 this disease was supposed to be caused by a fungus named *Hymenochaete noxia*. From that year to 1932, the causal fungus was considered to be one of the typical *Fomes* type which was named *Fomes lamaoensis*, Murr. In 1932 Corner's article, entitled "The Identification of the Brown-Root Fungus", appeared, and he concluded that the true cause of brown-root disease was a new fungus

which had previously been confused with *F. lamaensis* (= *Lamaoensis*), which he named *Fomes noxius*, sp. n.

This work of Corner on the fungus causing brown-root disease of many tropical cultivated plants, including rubber trees, has swept away much confusion. The disease has been known for a longer period than any other root disease on rubber, and specimens of the fungus, obtained from Bread-fruit trees in Samoa, were examined by Berkeley in 1875. It was recorded on Tea in India, in 1887, by Cunningham; in later years, on *Hevea* and numerous crops by other investigators.

It is rather difficult to explain the present position succinctly, and the best way to put forward a clear presentation will be to summarise the established details. Before summarising, it is legitimate to remark that many statements made by various investigators in the past must be doubted. The writer cannot support Weir's observations in Malaya, though he has had the subject under close observation since 1931. Further investigation is required, but as the disease is of little practical importance in Malaya, it is likely to be some time before further attention can be given to it. However, there is need for reinvestigation of this root disease in Malaya whenever time permits.

SUMMARY. *Cause.*—The history relating to the determination of the fungus as *Fomes lamaoensis*, Murr., is given in detail in Petch's article, page 171.

Corner's conclusions may be recorded as follows. The fungus causing the brown-root disease of rubber trees and tea bushes is not *F. lamaoensis*, Murr., but is a distinct species which is named *F. noxius*, sp. n. It is also the suspected cause of the stem-rot of *Elaeis* (Oil-Palms) in the East.

F. noxius differs morphologically from *F. lamaensis* in the wider hyphae, in the absence of hymenial setae and in the structure of the upper surface, and biologically in being a facultative parasite, and in growing in open situations, rarely, if ever, in the deep forest. *F. lamaensis* is a saprophyte in the forest and is very rarely found under estate conditions in Malaya. Murray, in his manual published in 1930, states that the fructifications of *F. lamaoensis* are very rarely found in Ceylon; this supports Corner's findings in Malaya.

Symptoms.—Roots attacked by brown-root disease, more especially the tap-root, are encrusted with a thick covering of earth and small stones 3–4 mm. thick (Fig. 25 *b*); this varies according to the type of soil. The mass is cemented to the roots by the mycelium of the fungus, which consists of tawny brown threads collected here and there into small sheets or nodules. In the early stages the predominating colour is brown, but as it grows older the fungus forms a black, brittle,

continuous covering over the brown masses of hyphae. In all stages, however, the disease is distinguished by the encrusting mass of stones and earth, which cannot readily be washed from the root.

The diseased woody tissue is soft and permeated by fine brown lines which are the edges of plates of brown fungus tissue (Fig. 25 *a*).

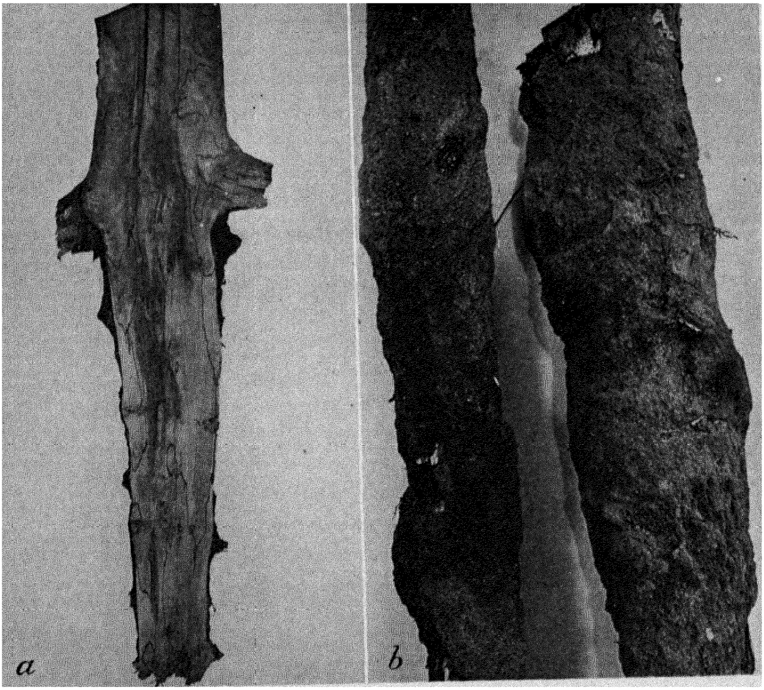

FIG. 25.—(*a*) Tap-root of young rubber tree affected by brown-root disease. Split open to show fine, brown lines of fungus tissue developed in diseased woody tissues. (*b*) External appearance of rubber roots attacked by brown-root disease, showing thick, earthy covering encrusting diseased roots.

When the decay is advanced, this brown tissue may form honeycomb-like structures in the wood.

It has been mentioned above that the encrusting mass of soil and stones is cemented to the roots by the mycelium of the fungus. The hyphae of the mycelium have the power of secreting mucilage, possibly in copious amounts, and the production of this substance, capable of binding the soil and stones tightly together, results in the appearance of the typical symptoms. Many fungi possess this power of secreting mucilage in the presence of adequate quantities of water;

this was demonstrated in 1922, in relation to brown-root disease itself, by the writer. It seems very probable, therefore, that any soil fungus, with brown hyphae capable of secreting mucilage, might produce typical symptoms of brown-root disease, if associated with individual trees of any particular crop. This fact may have some significance in connection with the large number of plants which have been reported as hosts for brown-root disease, a list of which is given at the end of this section for those people interested.

Spread and Control.—Few remarks are necessary under this heading. Spread is entirely by root-contact. The *Fomes* group of fungi causing root diseases of rubber trees are thus seen to constitute a series in which spread is entirely by root-contact, and the chief distinguishing features which characterise the three root diseases caused by *F. lignosus*, *G. pseudoferreum* and *F. noxius* are rapidity of appearance and extent of spread in area. Our experience of *F. noxius* on young trees in Malaya is that the disease appears only in single cases; thus, as long as root-contact has not been established in young plantations, there is no reason to fear active spread.

The only control action necessary is to remove dead trees and roots of diseased trees as completely as possible.

FURTHER INFORMATION.—The foregoing summary provides the gist of the reliable information obtained up to date, which is applicable to rubber plantations in Malaya. More detailed information respecting the disease generally is given in the following quotations.

The first extracts are copied from Corner's article and include the full description of *F. noxius*. This is followed by Petch's description of brown-root disease in Ceylon and Weir's remarks on some observations on the disease in Malaya.

(1) FOMES NOXIUS, CORNER

That it is the true *F. lamaensis* and that *F. williamsii* is a synonym, as Bresadola first noted, I have checked by microscopic examination of the types. Both types are in the herbarium at the New York Botanic Gardens and were collected by R. S. Williams on the Lamao River, P.I. They were described by Murrill in the same paper and on the same page in terms that are almost identical, though Murrill seems not to have noticed any similarity, and in the next year he assigned *F. williamsii* to *F. endothejus*, Berk., which, as Bresadola and Lloyd remarked, is utterly false, since *F. endothejus* is a species with brown spores and without setae. The description of *F. lamaensis* came first and this name therefore has priority. Bresadola substituted the name "*williamsii*", in which he was followed by Patouillard, apparently on the ground that the fruit-bodies in the type collection of *F. williamsii*, being larger than those in the type collection

of *F. lamaensis,* represented what he called "status adultus", those of *F. lamaensis* being the "status juvenilis" of the species. But this notion seems to have arisen from a remarkable misunderstanding. In the first place, the term "adult" cannot be applied to fruit-bodies of the *Fomes* kind which are virtually of unlimited growth and which continue to produce basidiospores from a very early stage, unless it is reserved for those fructifications which do produce basidiospores and so must then be applied to every state but the primordial knob, in which case the terms "mature" and "immature" seem more appropriate. But the fruit-bodies in the type collections of both species are all mature, though in neither can they be regarded as full-grown, since the fruit-bodies are perennial and much larger ones are easy to find elsewhere. In the second place, it seems that the terms "status juvenilis" and "status adultus" (which can mean only immature and mature) were confused with the terms "imperfect state" and "perfect state" in their mycological sense, and thus the rule of procedure for the radically different proposition when a *fungus imperfectus* is joined with an ascomycete or basidiomycete was applied also. It is important that this point should be clear, or it may become lawful to substitute many other names for the singular reason that they were given to bigger specimens of the same species.

The species name, taken from the place of discovery, Lloyd changed to "lamaoensis", which etymologically may be the more correct, and he has been followed by others. But one must keep to the original spelling, as it is clearly no misprint. The orgin of the name "lamao" is, moreover, uncertain. Is it a native word, or is it derived from the Spanish "lama", meaning "mud" or "flat swampy land" (Latin, *lama-ae*), or as seems most likely, from "la mano", meaning the hand, which has suffered contraction and fusion into "lamao", for there is also a Point Lamao?

Lloyd has explained the late discovery of this species, which is so common in the East. It was mistaken for *F. ignarius.* In the herbarium at Leiden he found many collections which had been sent from Java nearly a hundred years ago and thus referred.

With reference to the fungus which he considers the actual cause of brown-root disease, i.e. *Fomes noxius* sp. n., Corner states:

That this species is the cause of the brown-root of rubber trees, I have proved by examining specimens of the fungus from diseased trees in Malaya, as well as one of the collections from Ceylon which Petch sent to Lloyd for determination. I presume that it causes the brown-root of tea-bushes too, though I have not had the opportunity of examining specimens. It is also the suspected cause of the stem-rot of the oil-palm (*Elaeis guineensis*) in the East Indies. I examined several specimens from diseased palms which Thompson submitted for identification, and it is the species referred to in his paper as "*Fomes* sp. resembling *F. pachyphloeus,* Pat." (I was first struck by the large size of the extrahymenial setae in the dissepiments, which are like those of *F. pachyphloeus* rather than *F. lamaensis.*) Lately I have examined other specimens from diseased oil-palms in Sumatra and found them to be the same species. It is probably

a widespread parasite both in Africa and the East, since I have little doubt that the diseases which have been attributed recently to *F. lamaensis* will be found to have been caused by *F. noxius.*

The only other case which I have met with is that of a Flame of the Forest tree, *Delonix regia*, in the Singapore Botanic Gardens; the fungus, which had evidently entered by the roots, developed fruit-bodies at the collar of the tree and caused the branches of the tree to die-back to such an extent that the tree had to be cut down. I have not seen it parasitic in the forest.

FOMES NOXIUS SP. N.

Effuso-reflexed, pilei applanate, dimidiate, slightly ascending, up to 13·5 cm. radius, 25 cm. wide; resupinate part spreading up to 35 cm. wide.

Upper-side as in *F. lamaensis, rapidly glabrescent; growing margin white, creamy-white or pale ochraceous.*

Flesh 6–19 mm. thick at the base, rarely up to 5 cm. thick, 1·5–12 mm. at 5 mm. from the margin; 0·5–2 mm. in the resupinate part, texture and colour as in *F. lamaensis*; crust 0·5–1 mm. thick; black crustaceous lines and mycelial strands as in *F. lamaensis.*

Tubes short in the first season, 2–5 mm. at the base, 0·3–1·5 mm. at 5 mm. from the margin, developing 2–5 layers each 1–3 mm. thick with a thin intervening layer of flesh 0·5–1 mm. thick with a total thickness up to 11 mm., carbonaceous, concolorous with *F. lamaensis*; pores as in *F. lamaensis*, rather smaller, 80–110μ wide, dissepiments 40–100μ thick.

Spores as in *F. lamaensis*, rather larger, $3{\cdot}5$–$4{\cdot}5 \times 3{\cdot}0$–$3{\cdot}5$, with one gutta 1–2·5$\mu$ wide.

Basidia and cystidia as in *F. lamaensis*, cystidia sparse. Hymenial setae none.

Extrahymenial setae in the flesh up to 600μ long $\times$ 4–10μ wide, in the dissepiments up to 100μ long $\times$ 9–16μ wide.

Generative hyphae 2·5–5μ wide.

Hab. saprophytic or parasitic at the base of trees in clearings, estates or secondary jungle.

I made several observations on the rate of development of the fruit-bodies as they came up on some logs in the Botanic Gardens; I had the logs put in a shady place and well watered except in rainy weather.

The primordium appears on the surface of the wood as a minute, creamy-white, villose speck, 0·5–1 mm. wide. It does not develop straightway into the hemispherical primordium of the pileus even on vertical surfaces, but it grows at the periphery over the surface of the wood to form a circular, or irregular, resupinate patch about 0·5 mm. thick. The rate of marginal growth of this patch, i.e. the rate of increase in radius, varies considerably according to the supply of water, the humidity of the air and the age of the patch. The maximum rate which I obtained was 2 mm. *per diem* (24 hours). If conditions are favourable, it appears that a rate of 1–1·5 mm. *per diem* is soon reached and may be maintained until the patch is 10 cm. wide and possibly more. But if the air is dry, growth is much impeded and the rate falls to 0·1–0·3 mm. *per diem*; in several cases,

even though the logs were watered heavily twice daily, growth ceased altogether in sunny, rainless weather.

When the resupinate patches are 10–16 mm. wide, pores develop over the centre and a pore-field travels centrifugally at a distance of 2–3 mm. from the margin. On vertical surfaces pilei do not develop until the patches are 2–4 cm. wide, and in some cases not until they are 12 cm. wide. If the resupinate patches developed on the under-side of the log, then no pilei were formed, of course, until the margin of the resupinate part had spread on to an ascending surface.

The pileus arises as a short horizontal ridge 2–12 mm. long, from some part of the resupinate patch through the proliferation of the hyphae of the dissepiments, occasionally at the margin. The rate of marginal growth, i.e. the increase in the radius from the centre of attachment to the free margin of the bracket, corresponds with that of the resupinate part. The maximum rate which I observed was 1·6 mm. *per diem.* The growing margin of the pileus is as susceptible to dry air as that of the resupinate part, being very easily checked by a rainless day or two, though similarly, under favourable conditions it appears that a rate of 1–1·5 mm. *per diem* is soon attained. I did not succeed in growing pilei larger than 3·5 cm. in radius and 6·8 cm. wide, but one of these had a rate of marginal growth of 1·6 mm. *per diem* when 3·2 cm. in radius. Doubtless in large specimens the rate declines even under the most favourable conditions, as in *F. levigatus.*

When marginal growth is arrested for several days, the surface of the fruit-body blackens owing to the agglutination of the hyphal ends, and the fruit-bodies may remain in this state for any length of time up to three months at least and still be able to revive on the return of wet weather. In reviving, lateral hyphae sprout from the margin and under-side, sometimes from the upper-side also, and cover the fruit-body with a fresh, creamy-white down; then the radial growth of the limb and the down-growth of the tubes continue. These successive additions can easily be recognised in the structure of the fruit-bodies, since a thin crustaceous line extends through the flesh from the upper surface to the tubes where marginal growth has been arrested, and there are often thin layers of flesh between the successive layers of tubes.

These observations on the rate of growth are confirmed by Thompson's on the development of the fruit-bodies on the trunks of oil-palms. A bracket, 5 mm. in radius, took two months to develop, that is to say, at an average rate of marginal growth of 0·8 mm. *per diem.* On account of the slow growth and the extreme susceptibility to dryness, the fruit-bodies which develop under estate conditions, like those of *Ganoderma pseudoferreum*, are usually stunted and small, often abortive and mostly resupinate and have several short layers of tubes. The resupinate state might easily be mistaken for a *Poria*, as Patouillard mistook a similar state of *F. lamaensis*, and the species may have been described previously as a *Poria.* And as Petch has shown, the superficial sterile mycelium, which has projecting extrahymenial setae, was put originally in *Hymenochaete* with the *nomen nudum*, *H. noxia*, Berk.

(2) Brown-Root Disease

(*Fomes lamaoensis*, Murr.)

This disease appears to be the most widely-spread root disease of cultivated plants in the Eastern Tropics. It was originally found on Bread-fruit trees in Samoa, where it was said to cause serious damage. The next report of it was on Tea in Northern India; in this case the principal features of the disease were described by Cunningham, and though he did not discover what the fungus was, it is clear from his description that he was dealing with this disease. Similarly, Zimmermann found it attacking Coffee in Java, but was unable to ascertain the identity of the fungus which caused it.

It was first recorded on *Hevea* in Ceylon, and it is probably the commonest root disease of the Rubber tree in that country. Yet, except under special conditions, it does not cause so much damage as *Fomes lignosus.* The latter can spread independently through the soil from a jungle stump, and may attack a number of trees in one spot before any of them is so seriously affected as to show signs that there is something amiss. Brown-root disease, on the contrary, spreads very slowly, and, for all practical purposes, only along the roots of the tree; consequently it only infects the neighbouring trees when their roots are in contact with those of the diseased tree, and the progress of the fungus is so slow that, as a rule, the first affected tree is dead before the neighbouring trees are attacked. In general, therefore, only one tree is killed at each centre of infection, unless the dead tree is left standing for a long period.

When the dead tree is dug up, the special characters of Brown-Root disease are usually immediately evident, and, as a rule, there can be no mistake in the diagnosis. The roots are encrusted with a mass of sand, earth and small stones to a thickness of three or four millimetres; this mass is fastened to the root by the mycelium of the fungus, and consequently, cannot be washed off. The mycelium consists of tawny, brown threads, which are collected here and there into small sheets or loose masses, either on the surface or embedded in the crust of soil and stones. The colour of the mycelium varies, and one frequently finds brownish-white, or almost white, masses intermingled with the tawny brown. In the early stages the predominating colour of the mycelium is brown, and this is usually the case when the roots of a dead tree are examined. Hence the name Brown-Root disease. But when the disease has been established for a long time, and the fungus has grown older, it forms a black, brittle, continuous covering over the brown masses of hyphae, and the diseased root then appears chiefly black, The brown mycelium is, however, immediately discernible if the black crust is cut.

In all stages the encrusting mass of earth and stones, intermingled with brown threads, serves to distinguish this disease. The root looks as though it had been dipped in glue and then had soil and stones scattered over it. Bancroft stated that the surface of the root becomes dark brown and almost black, and for that reason the coolies in Malaya know the disease as "Sakit hitam".

In the case of young trees the encrusting mass is usually most strongly developed on the tap-root, and it may ascend up the stem for several inches. On old trees, however, the appearance may be different, especially if the tap-root is the part first attacked. In that case, owing to the slow effect of the disease, the tap-root may be in an advancing state of decay, before the fungus has spread to the laterals sufficiently to cause any marked symptoms in the crown. The cortex with its covering of earth and stones may by that time have disappeared completely from the tap-root, owing either to decay or to the attacks of white ants, and it is then necessary to examine the laterals to find the characteristic external appearance of the disease. But even when the outer crust has disappeared the disease may usually be identified by the appearance of the wood.

In some cases, after the tap-root has been attacked, the tree produces new roots at the collar, and these grow down vertically and take the place of the missing tap-root. As Bancroft has pointed out, this is an indication of the slow progress of the disease. I have, however, seen the same thing in a case of *Fomes lignosus*, where the disease had for some unknown reason been arrested after the tap-root had been destroyed.

If the encrusting mass is cut away, the cortex on the diseased roots is found to be brown, or brown mottled with small white patches internally. The diseased wood usually shows characteristic markings, though these may be of two entirely different types. In the one case the wood is soft and friable, with a network of fine brown lines, and even with a hand lens it can be seen that these lines are composed of brown hyphae. Thin sheets of brown hyphae run through the decaying wood, and these appear as brown lines when the wood is cut. This is the more frequent appearance in the lateral roots. In the other case the wood of the root is comparatively hard, and traversed by rather broad brown bands in which no hyphae are discernible. This may occur in the lateral roots, but is more usual at the base of the stem. There is some evidence that the appearance first described follows the second. In either case the wood in an advanced stage of decay may be honeycombed, the brown plates persisting after the tissue between them has almost completely decayed.

A few narrow black lines are usually present in the diseased roots, but the brown lines are more numerous. In advanced cases, black circles are sometimes found when the cortex is stripped off a diseased root.

Brown-Root disease, in its most general form, might be regarded as a "dry rot", but I have seen advanced cases where the honeycomb structure was well developed, in which the cells of the honeycomb were filled with water.

This disease often appears on old trees as a "collar rot", i.e. an area of rotten, decayed bark, more or less triangular in outline, and broadest below, extends upwards from ground-level on one side of the stem for a height of a foot or so. The wood behind this region is decayed and rotten, and may weather away, leaving a large cavity at the base of the tree. This effect is produced by an attack of the fungus on a lateral root, and its advance along the lateral to the base of the stem, which is attacked round the point of origin of the lateral. This mode of attack is very com-

mon in cases where the fungus first develops on *Cacao* stumps and spreads from them to *Hevea*, and in such cases it is easy to pick out the affected trees by the rotten patch of bark at the base, before any effect is observable in the crown. *Ustulina zonata* frequently works in the same way.

When the fungus has first attacked the tap-root, it often advances up the centre of the stem and causes a "heart-rot", i.e. it affects the central heartwood more rapidly than the outer, younger sapwood. A more or less conical decayed region extends up the centre of the stem, sometimes for a length of a couple of feet, the boundary being discoloured and evidently diseased, but still solid, while the inner parts are converted into a honeycomb structure with brown walls, with white fragments of the decayed wood in the cells. If such a stem is cut across above the evidently diseased part, a white covering of mycelium usually appears in the centre of the section within a few days.

A curious variant of the foregoing was recorded in one case. The tree had apparently had what is known as a "heart shake", i.e. the wood had split near the centre of the tree along the line of an annual ring. When the fungus grew up the stem it filled the crack with a thick felt of brown mycelium to a height of about three feet.

As indicated above, this disease is not confined to *Hevea*, but attacks cultivated plants of all kinds, except (as far as is known at present) the short-lived annuals. In Ceylon it has been recorded on Ceara Rubber, *Castilloa elastica*, Cacao, Tea, Dadap (*Erythrina*), Caravonica Cotton, Camphor, *Cinnamomum cassia*, *Erythroxylon coca*, *Brunfelsia americana*, *Thespesia populnea*, *Hura crepitans*, *Grevillea robusta*, *Codiaeum variegatum* (Croton), *Brownea grandiceps*, Jak (*Artocarpus integrifolia*).

In the Federated Malay States it has been found to attack *Hevea* and Camphor; Brooks and Sharples state that it is infrequent on the former, and usually attacks trees under two years of age, though Bancroft recorded that it appeared to be fairly common on certain areas. It has been recorded from Samoa on *Hevea*, *Castilloa*, Cacao, Bread-fruit and *Albizzia stipulata*, and from Java on *Hevea* and Coffee. In Southern India it is known to occur on Tea, on *Hevea*, and in Northern India on Tea and various shade trees. In West Africa it attacks *Hevea*, Cacao and *Funtumia*.

On new clearings the fungus spreads to the Rubber trees from decaying jungle stumps and rotting timber, and this may go on as long as either of these remain. In one case (on Tea) the fungus was found to spread to the Tea from decaying stumps of Na (*Mesua ferrea*), the Ceylon Ironwood, which were at least fourteen years old. But by far the greater number of cases which occur in Ceylon are on old Cacao land, after the Cacao has been felled.

Brown-Root disease is the only root disease of Cacao known in Ceylon. Comparatively few Cacao trees are killed by it, but the fungus develops freely on the Cacao stumps whenever the Cacao is cut down. In 1905 this occurred on several estates on which alternate lines of Cacao had been cut out to make room for Rubber, and in some cases it proved difficult to eradicate, owing to the large number of Cacao stumps, each of which was a potential centre of disease. When writing on this disease in 1911, it

was pointed out that where *Hevea* and Cacao had been interplanted it would ultimately become necessary to remove the Cacao; and when that step had been decided upon the Cacao should be uprooted, not merely cut down, if attacks of Brown-Root disease were to be avoided. Recent events have amply justified that statement. On several estates where the Cacao has been removed during the last five years, by merely felling the trees and leaving the stumps, Brown-Root disease has been rampant, upwards of ten per cent of the trees having been attacked. In such cases the cost of treating the disease has been much greater than the cost of removing the Cacao stumps originally would have been.

Another instance of the association of Brown-Root disease with the stumps of cultivated trees recently came to light in Ceylon. On one group of estates, the boundaries and roads were planted up with the white cotton, or Kapok tree, *Eriodendron anfractuosum*. Naturally, with such a large and rapidly growing tree, it soon became evident that they had to be taken out, and when that was done they were simply felled, and the stumps allowed to remain. In the course of a year or two, numbers of these stumps became centres of Brown-Root disease, which spread to and killed the adjacent Rubber.

Brown-Root disease has also been found to spread to Rubber from a felled *Hevea* log which had been accidentally buried during the construction of a road.

In the most general case Brown-Root disease spreads from one tree to another, or from a dead stump to a neighbouring tree, only when the roots of the two are in contact. Instances of this may be quite commonly seen where the disease has originated on Cacao stumps. But it may be worth while putting on record two cases which give some evidence that it might be possible for the mycelium to spread through the soil, at least for a short distance. In one case a Rubber stump was planted in a flower-pot at the laboratory, and in course of time the mycelium extended from the stump to the wall of the pot on one side, binding together the particles of soil in a mass about two inches thick. But it did not pass through the wall of the pot, as the mycelium of *Poria hypobrunnea* will do under similar conditions. In the other case the mycelium spread along dead leaves, etc., at the collar of a diseased *Brownea grandiceps* for a distance of about four inches all round. When this case was found, the mycelium had lost its hyphal character and had formed, on the under-side of the dead leaves, a black film covered with a brown powdery layer. This powdery layer can frequently be observed overlying the black crust on diseased roots; it consists of a number of minute spore-like bodies, which, however, do not appear to be true spores.

Though, as already stated, this disease is often associated with decaying stumps and timber, there are very many cases in Rubber, or Tea, or on ornamental trees in Botanic Gardens, in which no stump or decaying timber can be found anywhere in the immediate neighbourhood. In such cases it is obvious that infection must take place by means of spores conveyed to the plant by wind or other agency. But here, we were until quite recently faced with the difficulty that no one had been able to find the spores of

the fungus, or, indeed, had met with the fructifications of the fungus in other than a rudimentary condition. As a rule, a dead tree is found and dug up before the fructifications have developed, and the treatment which will cause the production of the fructification of, say, *Fomes lignosus*, in the laboratory from diseased roots is usually unsuccessful in the case of Brown-Root disease. Even when dead trees have been left standing for some years, until they have finally disappeared owing to the attacks of white ants, no fructification has been formed.

On young Rubber, or other small trees which have been killed by this disease, the fungus sometimes ascends the stem externally above the collar, and there forms a tawny or dark brown crust, free of earth and stones. In Ceylon these patches are usually small, not more than an inch or two in diameter, but in some countries they are said to cover the stem all around for a length of several inches. Bancroft stated that the only fructification he obtained in Malaya was a badly developed specimen on Camphor, but that he had seen specimens on Cacao from West Africa in which the brown crust ringed the stem at the collar for a distance of about three inches. These brown patches are minutely velvety, being covered with very small projecting bristles or setae. Such structures are characteristic of the genus *Hymenochaete*, the species of which form, as a rule, flat, encrusting, brown plates, velvety with the bristles in question. Hence it has been customary to consider that the fungus of Brown-Root disease is a *Hymenochaete*, and to adopt for it the name *Hymenochaete noxia*, which is that given by Berkeley to the fungus on Bread-fruit in Samoa.

But during the last few years, more particularly during 1917, perfect fructifications have been found in Ceylon on several occasions, on jungle stumps, on Tea and *Hevea* killed by Brown-Root disease, and on rotting *Hevea* logs. These show that the fungus is really a *Fomes*, and that the brown patches hitherto observed, the supposed *Hymenochaete*, are merely abortive attempts to produce the *Fomes* sporophore. This *Fomes* is bracket-shaped, often irregular, and consisting of several brackets fused together. The separate brackets are three to four inches broad, and about one third of an inch thick, and very hard. The upper surface is purple-brown, usually concentrically grooved, and glabrous. The lower surface is dark-brown, or almost black when moist. When broken in two it is seen to consist of a hard, dark, outer crust, with lighter brown tissue internally. The internal tissue usually shows a concentric zoning, with curved transverse lines parallel to the margin. The pore or tubes on the under surface are lined with setae, similar to those which occur on the supposed *Hymenochaete* patches. The fructification is peculiar in that its internal tissues are built up of two kinds of hyphae, the one thin-walled, like fungus hyphae in general, the other thick-walled and resembling the setae in structure. The name of this species is *Fomes lamaoensis*. It frequently occurs in resupinate form, i.e. lying flat on the root or stem.

The discovery of the *Fomes* fructification clears up the difficulty of accounting for the distribution of the disease. It is now evident that infection can be conveyed by wind-borne spores from the fructifications

on decaying stumps or timber in the jungle or elsewhere. But in Ceylon the fructification is by no means common, and it would seem that special climatic conditions are required for its development.

In illustration of the rate at which the disease spreads the following instance may be cited. *Hevea* was planted, 14 feet apart, in a single line round the boundary of an old-established Cacao estate. When the trees were eight years old, one of them died, from Brown-Root disease as was subsequently discovered. The tree was left standing and allowed to decay. Two years later the next tree in the line died and was likewise left to decay. After a further period of two years had elapsed, the next tree in the same direction along the line failed to recover after wintering and was evidently dying, and an examination of this tree and the two old decaying stumps proved that they had all been killed by Brown-Root disease. Some of the neighbouring Cacao was also killed during the four years, but the path of the fungus from one *Hevea* to the next had been along the rubber roots.

Anstead has recorded an experiment in which a diseased root was buried in contact with the roots of a healthy tree, with the result that the latter was infected and died.

Dead trees should be dug up, with as much of the roots as possible, and burnt. Any neighbouring stump should be similarly treated. The affected spot should be dug over, all dead wood collected and burnt, and lime forked in. In general, practically all the fungus is removed with the dead tree, and in many cases trenching has been dispensed with. But owing to the uncertainty of removing all lateral roots, it is better to err on the safe side, and to trench round the affected area.

When extensive attacks of Brown-Root disease occur on old Cacao, the decaying Cacao stumps must be dug up and burnt. This will generally entail forking over the whole area. It should then receive a dressing of lime at the rate of at least a ton an acre, in addition to the application of the usual quantity, sixty pounds, to the site of each dead tree. In such cases it is usually possible to detect many trees in an early state of the disease by noting the occurrence of patches of decayed bark at the collar where a diseased lateral joins the tap-root. These cases should be treated by removing the decayed lateral root and all diseased wood and bark at the base of the stem. The cavity should then be tarred, and it would be advisable to fill it up with cement or concrete.

The experiment of immediately replanting a tree of the same species in the place where one had just been killed by this disease was tried at Peradeniya several years ago, and the "supply" has remained healthy. It would therefore appear probable that vacancies might be filled as soon as all dead wood has been removed and the ground limed. But it would perhaps be safer to wait for about six months.

(3) Fomes lamaoensis

Fomes lamaoensis originally described from the Lamao River, Luzon, Philippines, and the cause of the brown-root rot of rubber has been found on almost all the estates visited and is shown to be a much more serious

cause of decay than was formerly believed. It has been found to cause the death of Mangosteen, Rambutan and Soursop by direct attack at the root-collar. It is chiefly responsible for a serious collar and tap-root decay of Guttapercha and Jelutong in the regions studied. The fungus has been found in four instances to cause a serious decay in the forks of rubber, resulting in the breakage of the branches at that point. These infections were due to spores carried either by wind or insects. The spore-producing capacity of the fungus, as determined by spore print-tests, is great and may continue indefinitely, but the fructifications are usually rapidly destroyed by insects. The mycelium of the fungus has been found to extend through the soil a distance of sixteen inches from a major infection and to attack the mature parts of a neighbouring root. This means of spread, which is favoured by the gelatinous nature of the hyphae and which causes the adherence of sand and gravel, explains the isolated spot infections.

List of Plants reported as Hosts of Brown-Root Disease

Artocarpus incisa, L.	Bread-fruit tree
Thea sinensis, L.	Tea
Coffea spp. (various)	Coffee
Hevea brasiliensis, Müll-Arg.	Rubber
Manihot glaziovii, Müll-Arg.	Ceara Rubber
Theobroma cacao, L.	Cacao
Castilloa elastica, Cerv.	Ule, or South American Rubber Tree
Erythrina, spp.[1]	Dadap
Gossypium barbadense, L.	Caravonica Cotton or Sea Island Cotton
Cinnamomum camphora, T. Nees & Eberm.	Camphor
Cinnamomum cassia, Blume.	Cassia bark
Erythroxylon coca, Lam.	Coca
Brunfelsia americana, L.	
Thespesia populnea, Sol.	Mahoe
Hura crepitans, L.	Sand-box tree
Grevillea robusta, A. Cunn.	Silky Oak
Codiaeum variegatum, Blume	Croton
Brownea grandiceps, Jacq. ?	*B. coccinea*, Jacq. is the Mountain Rose

[1] There are several species of *Erythrina* known in the tropics. *E. lithosperma*, Blume, is known as "Dadap" in Burma and Malaya; *E. indica*, Lan., is also known under the same name. The true "Dadap" of Java is *E. hypophlorus*, Boerl, while *E. umbrosa*, H. B. & K., is the "Immortelle" of the W. Indies. I am indebted to Dr. S. F. Ashby for this information.

Artocarpus integrifolia, L.	Jak
Albizzia stipulata, Boiv.	Sau
Funtumia (*elastica* ?), Stapf.	Lagos Rubber Tree
Mesua ferrea, L.	Iron-wood
Eriodendron anfractuosum, D.C.	Kapok
Garcinia mangostana, L.	Mangosteen
Nephelium lappaceum, L.	Rambutan
Anona muricata, L.	Soursop
Palaquium oblongifolium, Burck. or *Palaquium obovatum*, Engl.	Guttapercha
Dyera laxiflora, Hook.	Jelutong
Elaeis guinnensis, Jacq.	African Oil-Palm
Delonix regia, Rafin. *Poinciana regia*, Bojer.	Flame of the Forest—Flamboyant

CHAPTER X

OTHER ROOT AFFECTIONS AND SOME PROBLEMS RELATING TO ROOT DISEASES

Root Affections reported by other Investigators—Remarks regarding Fungi forming Rhizomorphs—Thinning-out, a Factor closely affecting the Spread of Root Diseases caused by *Fomes* spp.—Root Diseases in Rubber Areas planted on Land previously cultivated in other Crops—Root Diseases of Rubber in Malaya and *Rhizoctonia bataticola* (Taub.), Butler—Replanting of old Diseased Areas in Malaya—Costs of Replanting on old Rubber Areas.

ROOT AFFECTIONS REPORTED BY OTHER INVESTIGATORS

THERE are records of other fungi causing root diseases of rubber trees in Java, Ceylon and Malaya, but none of these are of importance in Malaya at the present time. Steinmann, in Java, records *Xylaria thwaitesii*, Cooke, as a root disease of rubber and also described an unnamed root-rot. Petch and Murray record the same fungus disease in Ceylon, and the latter remarks that though it is of extremely rare occurrence, it is considered worthy of mention owing to its severity in the cases recorded. The fungus, *Poria hypobrunnea*, Petch, is recorded from Ceylon as the cause of a root disease on rubber, but this again, according to Murray, is one of the most uncommon to which *Hevea* is prone. Brooks, in Malaya, recorded *Polyporus rugulosus*, Lev., as the possible cause of a root disease, but this has not been confirmed. Small in Ceylon has recently made strong claims for the parasitism of *Rhizoctonia bataticola* (= *Macrophomina phaseoli*), but these have not received support from comprehensive work since carried out in Java and Malaya.

With the object of covering the ground thoroughly, the following short descriptions of the above-mentioned diseases are taken from Murray's Manual of rubber diseases.

(*a*) PORIA HYPOBRUNNEA, PETCH

Red-root disease caused by this fungus is, in Ceylon, one of the most uncommon to which *Hevea* is prone. It originates from old jungle stumps and more particularly from *Hevea* logs.

Symptoms.—The appearance of diseased roots varies somewhat according to the age of the tree attacked. On young trees the mycelium forms stout red strands on the exterior of the tap-root. If cut, these strands are seen to be white internally. When old the strands turn black.

The root is often found encrusted with stones and earth as in Brown-Root disease, though never to so great an extent. The diseased wood is soft and friable and permeated with red sheets.

In older trees the diagnosis is often more difficult. The mycelium may all have turned black though red strands are sometimes found on a recently attacked lateral root. The diseased wood is generally soft and wet and exposed wood surfaces are red-brown in colour.

The fructification is uncommon but is sometimes found at the collar of a diseased tree. It forms a flat plate closely applied to the surface of the root or stem. When young it is yellowish-white but subsequently turns reddish-brown. The upper part consists of a layer of small tubes which are seen in a surface view as small holes.

Control.—The treatment is the same as for *Fomes lignosus.*

It should be noted here that this fungus causes a disease which in some respects is similar to that caused by *F. lamaoensis*. If the disease is uncommon and only single cases are found, the method of control would be as given for brown-root disease rather than for *F. lignosus*.

Xylaria thwaitesii

X. thwaitesii, as a cause of root diseases of *Hevea* in Ceylon, is of extremely rare occurrence. It is considered worthy of mention, however, owing to its comparative severity in the few cases recorded. The disease has only been reported from the Kegalle district in Ceylon; it also occurs in Java and Indo-China.

Symptoms.—The external mycelium of the fungus is represented by flat irregular bands of variable width on the surface of affected roots. These are white when young and are thus seen on the growing margin of the mycelium. They soon, however, become black and form an extensive network over the root, the bands coalescing in places to form irregular black patches. In this condition the external appearance is somewhat similar to an advanced case of Brown-Root disease.

The inner cortex is yellowish-brown in colour, and friable. Where the tap-root or a large lateral is attacked, latex is often found to have exuded from the cortex in numerous places and formed large lumps of black scrap.

In advanced cases the appearance of the wood of diseased roots is quite characteristic. On splitting the roots longitudinally the central region is sometimes found to be greyish-brown in colour, the wood being hard yet moist. This region may be delimited by a black line from the outer wood, which is yellowish-brown in colour and somewhat more decayed. It is noteworthy that the wood remains quite hard until the final stages of decay. The extreme wetness of thoroughly diseased roots is a striking feature; on breaking a root, water will often spurt into the face. This combination of hardness and wetness is quite distinct from the effect produced by any other of the root fungi. The fungus appears to spread very slowly and in this respect is comparable with *Fomes lamaoensis,* the cause of Brown-Root disease.

The fungus will apparently not attack exposed portions of roots.

Where an affected root comes to the surface the portion lying on and under the ground is diseased, while the upper part exposed to the air is quite healthy. The margin of the diseased tissues is sharply delimited and becomes marked by a line of callus growth from the healthy portion. It is along this line, i.e. where a diseased root comes to the surface, that the fructifications are mostly found.

The fructification consists of a cluster of club-shaped growths, arising from a basal mass. Three or four stout stalks arise which may divide into numerous finger-like protuberances. When found in the field the "clubs" are usually a dirty white at the extremity, darkening in colour down to the base. Subsequently they turn black. The fructification is usually one to three inches in height and the basal mass about two inches in diameter. When mature, the upper part of the club-shaped stroma bears perithecia containing spores.

Control.—As for other root diseases.

RHIZOCTONIA BATATICOLA = MACROPHOMINA PHASEOLI

It has already been mentioned that the importance of this fungus as a cause of a root disease of *Hevea* is not yet clearly known. *Rhizoctonia* is probably capable of attacking healthy roots under certain conditions, and since future experiments may prove it to be of greater importance than it is now commonly regarded, it is as well that the planter should be acquainted with the symptoms of disease and appearance of the fungus in rubber roots. The fungus has been identified as *Macrophomina phaseoli* and should correctly be called by this name. To avoid confusion, however, the former name of *Rhizoctonia bataticola* will be used.

Symptoms.—*Rhizoctonia* enters the root system *via* the small feeding roots and thence travels slowly upwards into the longer roots. It is in the fine laterals that the fungus is most commonly found. It produces no conspicuous vegetative mycelium either externally or in the tissues of the root and will therefore often escape the eye of even the trained observer. In an affected root the inner layers of the cortex are attacked, and the latter, therefore, usually lies as a loose sheath over the wood. If the cortex is removed the wood is found to be hard, dry and brittle, and is studded throughout with very minute black spots. These are sclerotia, or resting bodies of the fungus, and are also found on the inside of the cortex. Fine black, dark-brown lines are also sometimes seen in the wood. The symptoms are the same in large roots though larger sclerotia may be found. Attacked roots are undoubtedly killed and rendered functionless, but it has been argued that it is only after the tree has been weakened by other fungal attack or by some physiological cause that *Rhizoctonia* is able to gain entrance.

Control.—In the present stage of our knowledge no control measures can be suggested, beyond increasing the vitality of the trees by cultivation methods.

The small, black, rounded sclerotia from which the fungus takes the name *Rhizoctonia bataticola* (Taub.), Butler, are not spores nor

spore-producing fructifications, but are simply aggregated masses of mycelial tissues which can resist adverse conditions. This subject has already been mentioned, and is dealt with in some detail later. It may be pointed out here, however, that if spores are ever found to be developed by the fungus, a change in name according to the nature of the spore-form will be required. Thus, the name given to the imperfect, pycnidial spore-form, i.e. *Macrophomina phaseoli* (Taub.), Ashby, would be used in preference to *R. bataticola* by systematic workers. But certain investigators are still uncertain as to whether or not the name *M. phaseoli* can be accepted.

Polyporus rugulosus

Brooks describes this possible fungus affection as follows:

> On several occasions another polyporoid fungus was seen growing at the collar or upon exposed lateral roots of diseased rubber trees and it seemed likely that this fungus was the cause of the disease from which the trees suffered, although inoculation experiments are needed to settle this point definitely. The tissues of the host near the fructifications were invariably decayed, the foliage of the affected trees became thin, and the branches died back after the manner of trees attacked by a slowly growing root parasite. I saw this disease in trees which were in tapping, and it appeared to be more frequent in badly-drained, low-lying estates than upon undulating land. One tree severely attacked by this fungus had been previously invaded by white ants.
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> The fructifications of this fungus are often densely imbricate and, in the aggregate, form large masses, several inches across, although a single pileus is only an inch or two in diameter. The upper surface is smooth, brownish and zoned; the under pore-bearing surface is white when young, becoming yellowish-brown with age; the pores are minute; the substance of the fructification is thin, and although fleshy when young is leathery at maturity. Both in the colour of the pores and in the much thinner substance, the fructifications of this fungus differ markedly from *F. lignosus*.
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> I am indebted to Miss Wakefield of the Royal Botanic Gardens, Kew, for kindly identifying this fungus as the *Polyporus rugulosus* of Leveille. The type specimen of this fungus was obtained from tree-trunks in Java, and was described by Leveille in 1844. Saccardo has since placed the fungus in the genus *Fomes*, but on account of the texture of the fungus when young it is preferable to retain the original name. I have been unable to find any previous record of this fungus on rubber trees.

I have seen no confirmation of this finding in Malaya.

As the fungus must be of rare occurrence, treatment should be on the same lines as for *F. noxius*, i.e. eradication of diseased trees and roots from the soil.

Steinmann reports a "root-rot" in a general sort of way, and the following translation is taken from his book:

Root-Rot

This is the effect of the influence of stagnant water on the root system of *Hevea*. It occurs exclusively in low-lying lands with heavy soils. The symptoms, collectively called root-rot, are caused by unfavourable conditions of the soil, especially in connection with supply of air; a characteristic is the absence of mycelium. The structure of the soil, of course, plays an important part. Most cases of root-rot are found on heavy clay soils which suffer from lack of air supply and from excessive moistness; it is less common on loose porous sandy soils which are better able to stand the disastrous consequences of temporary flooding.

Progress of the Disease.—In some cases of root-rot the above-ground parts of the tree do not show any abnormal signs and the disease does not become apparent before the trees are blown down. In most cases the crowns are sparse on top and start dying back. Cases such as happened in 1918 on an estate in Sumatra where, owing to a flood lasting two months, about 100,000 trees of six to eight years old were killed, fortunately are an exception.

The roots are usually blue-black to black on the outside; their bark is completely rotten owing to the action of anaerobic bacteria due to lack of oxygen. The very first measure to prevent root-rot is proper drainage to ensure thorough carrying-off of the water. On such low-lying land it is advisable to dig wide, straight parallel drains following the slope of the land. In accordance with the volume of water to be carried off and the fall of the land, these main drains must be made 8–20 feet wide and 6½–8 ft. deep to lower the level of the ground water to that depth. In low flat land, the number, width and depth of the secondary drains depends on the character of the soil. If the soil is clayey, the distance between them must be less than is needed in sandy soils; with marshy soils it may even be necessary to dig drains between all rows or every second or third row. For the rest we refer to what has been said on this subject in the *Handbuch voor de Rubber Cultuure*, p. 72.

Van Overeem in 1924 recorded a case of the black-root disease (*Rosellinia* sp.) affecting rubber and coffee. His English summary is as follows:

In a rubber and coffee estate in Kediri some cases of the black-root disease affecting coffee were stated and also a single case of the same disease attacking *Hevea*. Obviously the latter had been infected by the coffee.

Already as early as 1910, Zimmermann gave detailed description of the black-root disease in coffee but the fungus could not be identified. An affection of *Hevea* by this disease has, until lately, never been observed. The fungus forms on the roots of the trees fine, black, slightly flattened strands which in some places were profusely ramified and formed a kind

of netting which is a characteristic of *Rosellinia*. The specific name of the fungus is probably *R. bunodes* (Berk. et Broom), Sacc., but absolute certainty on this point could not be obtained, organs of fructifications being absolutely wanting. The symptoms shown by the roots of coffee were less typical; however, we do not doubt in the least that the disease was caused by the same fungus.

The attack of *Hevea* by the black-root disease should not give rise to alarm, as *Rosellinia* occurs everywhere and up till now not a single case of this fungus affecting *Hevea* was mentioned.

The name black-root disease is to be remembered for the above-described disease, the identical organism being known under the same name for tea and coffee. For *Sphaerostilbe repens*, this name must be rejected as the use of it might cause confusion, and in this species the strands are not black.

Remarks regarding Fungi, forming Rhizomorphs

It will now be appreciated that the production of rhizomorphs by root-disease fungi is a subject of considerable importance to both investigators and laymen. It may be more interesting to the former, because there is very little information available in the literature, even from the structural point of view. Every student of fungi is aware of the typical formation of rhizomorphs by the fusion of hyphae running longitudinally (well shown in *Fomes lignosus*); the habit of longitudinal growth by means of an apical meristem (well seen in *Sphaerostilbe repens*); the habit of anastomosing to form a network (seen in *F. lignosus* and *S. repens*); whilst in some cases, individual rhizomorphs grow together so closely as to form continuous membranes (shown by *Ganoderma pseudoferreum*). The typical structure of the common rhizomorph is best shown by *S. repens* (Fig. 11).

An attempt will now be made to impart some further general information. All the important root diseases of rubber trees in Malaya are characterised by the possession of some form of aggregated mycelial structures. These bodies should prove of utility in resisting adverse conditions, a function considered to be one of the main attributes of rhizomorphs, and four of the five fungi concerned produce these structures in typical form.

Root diseases caused by fungi which form rhizomorphs are not confined to Malaya, nor to the rubber tree. The remarks which follow naturally refer chiefly to *Fomes lignosus* and *Ganoderma pseudoferreum*, but many observations may be taken to apply to rhizomorphs generally.

The root diseases under consideration are liable to occur in any part of the world in woody crops planted on land recently cleared of virgin

forest. The actual parasites concerned and their relative importance vary in different countries and in different crops.

The group has attained its maximum economic importance in the tropics, where the climate favours the evolution of vegetative propagation, and where the first crops taken on virgin land are quickly maturing tree crops such as rubber, coffee, tea and cocoa, etc.

In Malaya, the rhizomorphs of *F. lignosus* and *G. pseudoferreum* obviously provide an efficient means of vegetative propagation. Therefore the production of fructifications and spores may be considered a laborious process in these two cases, and the formation of rhizomorphs provides a special means of short-circuiting the slow development of the fructifications.

The question is often asked why the root parasites never seem to do any obvious damage in standing jungle although they have such an effective and easy method of propagation at their disposal. It has already been stated that the jungle conditions represent a delicate state of equilibrium established over very long periods of time. Now the root-disease fungi, along with their neighbours, are kept in check by natural competition. They only obtain dominance here and there, and the damage done is not noticeable. When the jungle is felled, the equilibrium is destroyed and the rhizomorph-forming fungi find the new conditions entirely to their liking from the point of view of spread.

Before a Malayan jungle area is felled, the various root-disease fungi form, through their rhizomorphs, continuous individual "networks", extending over the whole area. The size of the "meshes", i.e. the extent of infection, depends in the lie of the land, type of soil, rainfall, etc., but largely on the individual characters (such as vigour and mobility) of the particular parasites concerned. This latter factor also determines the size of the individual "knots", i.e. of the spots in the jungle where the fungi have obtained dominance over their competitors. In undisturbed jungle these "networks" are continually changing their form through rhizomorph activity.

The three root diseases on rubber trees caused by *F. lignosus*, *G. pseudoferreum* and *F. noxius* differ fundamentally only in regard to the development of maximum activity, i.e. whether they are rapidly or more slowly developing fungi. It may be useful to repeat that *F. lignosus* is an exceedingly vigorous and mobile fungus with a diffuse, far-spreading, rapidly growing rhizomorph system resulting in the formation of jungle networks which are ill-defined, the meshes being small and the knots numerous, diffuse and almost merging into each other. The fungus is a quick-acting wood-destroyer

and the infected roots rot away rapidly after felling. The attack on the succeeding rubber plantations therefore develops very soon after planting, is widespread, and usually dies down before the trees reach maturity.

The cause of red-root disease, *Ganoderma pseudoferreum*, is on the other hand a more compact, slowly acting fungus and the jungle networks are therefore wide-meshed, the knots being relatively few and restricted in size, and taking a long time to rot away after felling. This disease, therefore, develops from widely spaced, concentrated centres in the subsequent stand of rubber, but the onslaught is spread over a long time. In the immature stand, where the chance of spread of the disease from tree to tree by root-contact is slight, the loss of trees is small in number, but in the mature stand the disease becomes a serious menace. The infected jungle timber remains active long after the roots of the rubber trees have become closely intertwined all over the clearing, and under favourable conditions the disease spreads gradually from tree to tree away from the knots of jungle infection, thus forming the disease patches so familiar in present-day stands of old rubber. Red-root disease is therefore typical of old areas, although it does occur to a small extent in immature stands.

Brown-root disease, caused by *F. noxius*, does not call for any special comment, for it occurs but rarely on rubber trees in Malaya and therefore is of little practical importance to planters in that country.

The root parasites of the rubber tree, capable of forming rhizomorphs, possess in these organs a powerful weapon of attack and propagation. The rhizomorphs have, however, many limitations, and these can be taken full advantage of when planning a scheme of control for root disease. The main limitations are:

(*a*) They cannot grow freely exposed to the air, hence their penetration of a host cannot take place above soil-level.

(*b*) They cannot grow straight through the soil, but require a continuous chain of roots along which to spread. It will be clear from (*c*) below that "chain of roots" refers to both living and dead roots. This does not greatly hinder the development of the fungus in the jungle, or in a planted clearing where the soil is full of interlacing roots. The need of a chain of roots, however, affords a line of treatment, viz. the relatively simple expedient of removing all buried timber from an infected area. This removes both sources of infection and rhizomorph system, making a clean sweep of infected material, and leaving the soil perfectly free.

In connection with the statement that rhizomorphs require a con-

tinuous chain of roots along which to spread, it should not be forgotten that most investigators incline to the view that *Fomes lignosus* has the power of free growth through the soil, and this seems to be generally accepted. Sufficient evidence has, however, been gathered to justify the above statement in respect of root diseases investigated in Malaya, but absolute evidence, which would settle this point definitely, is not yet forthcoming. Evidence obtained recently in young planted areas strongly favours the view that a continuous chain of roots is required for the rhizomorphs to spread freely in area.

(*c*) Although rhizomorphs can travel equally readily along the surface of dead or living roots, they can only penetrate and obtain nourishment from living roots. In a newly felled jungle area, therefore, the only potential sources of infection are the root systems of those trees which were infected by root disease before felling, and it is possible, without recourse to the costly alternative of complete clean clearing, to trace and remove all potential sources of infection before a loss of stand commences in the subsequent crop. This is a sound argument theoretically, and in one particular case it has proved so in practice. The same argument also applies to the treatment recommended for old rubber areas which have been heavily infected with root disease and are to be replanted.

The fundamental facts for root-disease control in Malayan rubber plantations may be shortly restated. As the root-disease fungi reside in decaying wood and not in the soil, the removal of infected roots from the soil by digging will completely eradicate root disease from an infected area. Soil sterilisation by the surface application of fungicides can never hope to control root disease. It may kill the growing rhizomorphs but it will only sterilise the surface of the sources of infection. As soon as the rain washes away the fungicide, new rhizomorphs will form, and parasitic activity will recommence. It will be well to emphasise that the use of copper sulphate solution, as recommended on page 130, is not for the purpose of soil sterilisation.

The digging of isolation trenches to hold up the spread of root disease is sound as long as certain conditions are fulfilled:

(*a*) Each separate jungle knot of disease must be completely encircled by the trench. This is easily attained in mature areas when treating red-root disease, but almost impossible to ensure when treating white-root disease. Trenches dug within the limits of a knot are useless.

(*b*) The trench around each knot must be dug beyond the limits of the advancing rhizomorph systems. This cannot be attained with certainty by digging trenches according to some arbitrary, geometri-

cal pattern. Trenching must be accompanied by root inspection.

(*c*) The trench must be deep enough to sever completely all root-contact between one side of the trench and the other, and must be kept open.

The subject of rhizomorphs has been treated at considerable length from one point of view. It is a very wide subject, however, and offers scope for many speculative considerations. In connection with the root diseases of rubber trees, all investigators will admit that four of the five important fungi dealt with produce rhizomorphs; three of them produce structures of the typical form, but in *Fomes noxius* the rhizomorphs are somewhat atypical, being masked by the thick covering of soil and stones found on diseased roots. *Ustulina zonata* does not produce rhizomorphs, but arguments will be advanced to show that from the functional standpoint this fungus does not differ greatly from the other fungi causing root diseases. An attempt will now be made shortly to put forward various points which appear of interest in this connection.

The first question to be answered is: How did rhizomorphs arise and for what purpose were they produced? It has been clearly stated that rhizomorphs are fundamentally aggregations of fungal hyphae, which, as seen at the present day, are of the greatest utility in the life-history, and especially in those fungi causing root diseases. They are the product of evolutionary change, as is the case in all organic developments. Certain authorities state "that rhizomorphs serve, as will be shown in the Basidiomycetes, for the transport of food". If food transport was originally the important function of these structures, they must have existed in saprophytic forms prior to any indication being given in the evolutionary sequence towards parasitism. In parasitic fungi, food transport has become a very subsidiary or secondary function of rhizomorphs in comparison with those of (*a*) preventing desiccation and (*b*) permitting extensive spread in area, to which major importance must be attached. All aggregations of hyphal tissue will help towards the former function (*a*). It appears legitimate, therefore, to consider that rhizomorphs were a common feature in saprophytic fungi for purpose of food transport, prior to the period when protective tendencies, which would prolong the continuity of, and ensure the spread of the species, were found to be developed in parasitic fungi.

If this view is accepted, the evolutionary transition from saprophytism to parasitism would most probably be through an intermediate stage of semi-parasitism. Because of its epiphytic phase, *F. lignosus* may well be considered to be a semi-parasitic fungus, for

during the epiphytic periods the parasitic activities must be suspended. This may be said to be due to the antagonistic influences of the host plant dominating the opposing ones possessed by the rhizomorphs. *Ganoderma pseudoferreum* is a definite holo-parasite and presumably *F. noxius* falls in the same class. *Sphaerostilbe repens* and *Ustulina zonata* do not fall within this group, but *F. lignosus* can definitely be considered the starting point of a series, followed by the more specialised forms of *Ganoderma pseudoferreum* and *Fomes noxius*.

After the parasitic habit has become stabilised, the main effort of parasitic fungi is directed to the one end-aim of all organic life, viz. preserving the continuity of the species. Extensive spread in area, permitted by the development of rhizomorphs in parasitic root fungi, is but a step towards this desired end. It may be as well to recall that methods of vegetative propagation, when effective, generally tend to replace methods of sexual reproduction necessitating the production of elaborate fructifications and spores.

A parasitic root fungus producing rhizomorphs must avoid any factors retarding its development, and its greatest danger lies in drying-out, i.e. desiccation. Therefore, the production in any particular species of special structures which will prevent desiccation will mark an advance upon others which retain their original form. It is remarked above that any aggregation of fungal hyphae, whether in the typical rhizomorphic form or not, may be considered an advance on simple hyphae in the matter of preventing desiccation. Gaumont and Dodge suggest the use of the term *plectenchyma* for aggregations of hyphal tissues. Thus when the question of prevention of desiccation is being considered, rhizomorphs are merely plectenchymatic tissues which assume a definite form.

Rhizomorphs may be considered as external plectenchymatic tissues in *F. lignosus*, *G. pseudoferreum* and *F. noxius*, or as internal plectenchymatic tissues when they are developed internally as in *Sphaerostilbe repens*. Internal plectenchyma will also apply to any aggregations of hyphal tissue in the form of black lines in *Ustulina zonata* and the brown lines in *F. noxius*.

All rhizomorphs are effective organs for the purpose of preventing desiccation, when they are allowed freely to develop in their natural, underground habitat. But when diseased roots are exposed to the atmosphere, distinctive differences between the various fungi concerned are noticeable. When the more severe conditions resulting from exposure have to be resisted, external fungal tissues, without special protective devices, will suffer to the greatest extent. *Fomes*

lignosus has no special devices and provides a typical example of a rhizomorph-producing fungus which is quickly dried out on exposure. *Ganoderma pseudoferreum* produces rhizomorphs which have a thickened outer skin, and this, as compared with *F. lignosus*, is more efficient in preventing rapid desiccation. The rhizomorphs of *F. noxius* are intermixed with a thick binding of soil and stones, and such a covering would form a very effective measure for preventing drying-out. The internal development of the rhizomorphs of *Sphaerostilbe repens* will result in more efficient protection than if they were developed externally, and the maximum protection will be enjoyed by fungi developing plates of plectenchymatic tissue internally, more especially if they are deeply placed in the diseased tissue, as is the case in *Ustulina zonata*. *Fomes noxius* also develops this type of internal plectenchyma, while *G. pseudoferreum* follows suit, though only to a limited extent.

From a functional point of view, it may be taken that the fungi causing the root diseases of the rubber tree form a series, with *F. lignosus* as the starting point, the least specialised against desiccation. From the point of view of withstanding desiccation, *F. noxius* and *S. repens* both stand in a comparatively favourable position, and neither fungus can really be given precedence in this respect.

On the above reasoning, the order in the series would fall as follows:

(1) *F. lignosus*
(2) *G. pseudoferreum*
(3) *S. repens*
(4) *F. noxius*
(5) *U. zonata*

If development of typical, external rhizomorphs is taken as the main criterion, then *F. noxius* becomes third in the list and *S. repens* fourth.

There is much evidence which would support the above views, while some could be quoted as antagonistic. But enough has been written to show that plant diseases of a particular type developing on the same crop should not be envisaged as isolated units, having little in common. In other words, the physiological aspects of the pathological problems under consideration should hold a much more important position than is usually thought to be necessary. The source of our present knowledge on root disease really developed from a short investigation by the writer on the fungi isolated from diseased roots of Camphor, and from diseased roots of rubber trees obtained from Ceylon and Malaya. All these showed typical symptoms of brown-

root disease, in so far as the thick encrusting, external mass of soil and stones, tightly bound to the roots, was a well-developed feature in all. All three fungi isolated were different morphologically, but were alike physiologically, for all excreted mucilage freely when grown on blocks of rubber wood in the presence of adequate supplies of moisture. This venture into the quest for the cause of brown-root disease formed merely a prelude for a much wider investigation of root-rots of rubber trees, but the opportunity did not arise until quite recent years, and the results are shown in full for the first time in this book.

THINNING-OUT, A FACTOR CLOSELY AFFECTING THE SPREAD OF ROOT DISEASES CAUSED BY FOMES SPECIES

Reference has already been made to the methods followed when planting up in Malaya, the outstanding feature of which is the practice of planting more trees per acre than is necessary. This ensures a sufficient number of trees remaining available to produce the most economical results when the time arrives to start tapping. The number of trees per acre must therefore be reduced at some time or other. Losses through root disease are usually expected even if not so numerous as to cause much anxiety. There are no fixed limits to the number of trees to be planted. It will probably be dictated by local fancy, but a common number lies between 150 and 200 per acre. Neither is the number of trees to be thinned-out at any particular period a fixed one; the number taken out is mainly directed by the fact that it is desirable to maintain the yield of latex at as high a level as possible. There is one guiding principle. The number of trees per acre must not be so reduced that a noticeable decrease takes place in the amount of dry rubber per acre obtained.

The disease losses in the early years are caused mainly by *Fomes lignosus*; the number lost by attacks of this fungus normally reaches a peak between the fourth and fifth year and from this time onwards the number of disease losses should decrease annually. Rubber planters may consider themselves fortunate that this feature is well marked in Malaya, but it must not be forgotten that the closely spaced disease knots formed by *Fomes lignosus* are not the only heritage left by the felled jungle. The wide-spaced disease knots, characteristic of *Ganoderma pseudoferreum*, still remain, and these are of primary importance in mature stands.

It has been stated that although rhizomorphs have certain limitations they form a very efficient means for effecting spread in area, if left undisturbed to continue their natural habit of growth below soil-

level, especially if a close, intertwining, continuous chain of roots exists. It has been emphasised that a continuous chain of roots is a necessity for the efficient spread of the root diseases caused by the *Fomes* type of fungi. The method of thinning-out of rubber trees usually adopted in the past was to cut them at ground-level, remove the trunk and branches from the plantation, often by burning, and to leave the tap-roots and the lateral roots to decay *in situ*. This method was adopted on the ground of expense, but while it saved immediate costs it provided ideal conditions for encouraging the spread of root diseases. As losses due to *Fomes lignosus* should be decreasing rapidly as the time for thinning-out approaches, the only root disease which needs serious consideration is that caused by *Ganoderma pseudoferreum*.

Another point to remember is that a vigorous rubber tree displays a certain amount of resistance to attacks of *G. pseudoferreum* by the production of adventitious roots, but there is no resistance offered by the parts of a rubber tree left in the soil after the upper parts have been removed by thinning-out. When the trunk of a tree is removed, the roots do not necessarily die with great rapidity. However, they become moribund and ultimately death follows. The loss of resistance to the attacks of the fungus may be considered an additional factor which will lead to the rapid spread of root disease after thinning-out.

The *modus operandi* of spread of root disease in thinned-out rubber areas may now be shortly described. The rhizomorphs will quickly withdraw from tissues where food material is becoming scarce, such as the roots of rubber trees left in the soil after thinning. Neighbouring healthy trees will then become infected rapidly, that is, if root-contact becomes definitely established between them and the non-extracted affected lateral roots of thinned-out trees, in which perhaps disease had been unsuspected. Thus the original jungle areas in which *G. pseudoferreum* had gained dominance are maintained without any evident increase in area until root-contact by healthy trees is made. This is governed by the spacing of the trees, but root-contact will be established between the fourth and the sixth year. Following this period, a slow spread in area may be expected until thinning-out is undertaken; afterwards a rapid acceleration will be effected as detailed above. About the eighth to the tenth year the disease becomes prominent and numerous diseased specimens may be found at this stage. It seems fairly obvious that there is little cause for fearing large losses of mature trees if the original disease knots can be removed in the early years and if thinning-out is done thoroughly, i.e. by extracting tap-roots and lateral roots.

In a general consideration of the root-disease position in Malaya, a great change has been brought about by the comparatively recent discovery that *Ganoderma pseudoferreum* was present in the earliest stages of the plantations, i.e. *foci* of diseased trees, affected by this fungus, could be found when they were not more than two years of age. But owing to its slow growth and underground habit, the "disease-areas" escaped detection for eight to ten years. Given such *foci* of infection and exceedingly favourable conditions for rapid spread by root-contact, it is not surprising to find large areas of old rubber now being killed by *G. pseudoferreum*. This is owing to the method of thinning-out adopted in the past. As noted previously, the position in the old rubber areas in Ceylon is, according to the records, materially different from that in Malaya. In that country, the fungus responsible for most of the damage in old rubber areas is *Fomes lignosus*.

Root Diseases in Rubber Areas planted on Land previously cultivated in other Crops

The root-disease problems which arise on Malayan rubber plantations as a result of the trees being planted on land which was previously under jungle, have been fully described. But in Ceylon cultivation of other crops was being carried on long before rubber planting was started; for instance, the cultivation of Coffee was a very profitable undertaking as long ago as 1870. Before the inception of the rubber industry, Malaya was a country not too well known from an agricultural point of view; in fact, there was very little agricultural development in the country. The prospects for the new industry appeared very bright when the profit-earning stage was reached by the first rubber plantations, and its full expansion and development could not possibly be estimated.

The crops chiefly grown in Ceylon before rubber were Coffee, Cacao and Tea. Of these crops, European planters were endeavouring, somewhat unsuccessfully, to cultivate Coffee in Malaya over rather limited areas. Sugar estates were also organised on some coastal areas in Malaya, usually under European supervision, but the area under this crop was not extensive. In Malacca and Kedah, there were fairly large acreages of Tapioca, chiefly by Chinese cultivators. When the rubber industry began rapidly to expand, the comparatively unprofitable Coffee, Sugar and Tapioca crops were quickly abandoned and the popular new crop substituted. The position was different in Ceylon, because the crops under cultivation were still profitable at the time. Profitable crops could not be rapidly abandoned without incurring

considerable risk, hence in order to be on the safe side, they were interplanted with rubber, until the heavy shade from the growing trees began to interfere with the normal development of the individual plants of the preceding crop. When this occurred, the latter were extracted and rubber was left as the sole crop. But in addition to establishing rubber plantations by interplanting areas carrying other crops, it is probable that rubber plantations exist in Ceylon which were planted directly on recently felled jungle land. If this be the case, then a true comparison is possible between rubber plantations in Ceylon and Malaya.

For Malaya, the statement can be made without fear of contradiction, that the state of the jungle soil in which the young rubber trees are planted, predetermines the future behaviour of these areas in respect of root diseases. It might be expected that the more general remark will apply, i.e. that in any country, any growth precedent to rubber, whether jungle or plantation crop, must have a very important influence on the types of root diseases which will develop in the new crop. Keeping in mind that *G. pseudoferreum* has not been recorded in Ceylon (though it causes practically the whole of the damage in old rubber areas in Malaya), and that brown-root disease can be considered rare in Malaya, the paragraph on page 169, copied from Petch's book, is of considerable interest. It refers to the common occurrence, in Ceylon, of brown-root disease on rubber trees planted upon old Cacao land, and indicates that the true explanation of the comparative rarity of brown-root disease on rubber trees in Malaya, viz. that, except in an experimental fashion, Cacao has never been planted up in the country. It may be added that the writer has never heard of one of the Cacao experiments proving successful.

There seems little doubt that whatever the type of land utilised for the planting of rubber, the root-disease problems which are likely to be encountered will depend entirely on the previous planting history of the areas. When rubber plantations replace other crops, either by being interplanted or by direct replacement, the root diseases which the plants are likely to contract will be those to which the replaced crop plants were susceptible, and which the latter contracted originally from jungle soil. So that root-disease problems might be expected to vary according as to whether the areas under consideration were previously under Coffee, Cacao, Tea, Sugar or Tapioca, or any other growth which might be mentioned, for all will probably show wide differences as regards their susceptibility to the fungi persisting from the original jungle and which are capable of causing root diseases. Thus, there are very strong reasons supporting the expectation that

root diseases may be very different on rubber plantations in Ceylon and Malaya.

If economic crops are planted successively, the perpetuation of a root disease caused by a fungus which is active in the original jungle is brought about only if the first or succeeding crops are susceptible to the particular fungus. If none of these are susceptible, the fungus can only continue existence as long as any undecayed jungle timber remains, and once this is removed, danger disappears. Jungle stumps and timber, in areas where they are allowed to decay naturally, are not prominent after a period of thirty years, though there may be some remnants of the largest, hardwood stumps still persisting. Therefore after thirty years the only disease centres remaining are those formed by the crop plants which have contracted the disease. If rubber-planting has been undertaken on areas where the original jungle stumps and timber have rotted away completely owing to the lapse of time, and a crop or crops of non-susceptible plants have been cultivated before the rubber, reports of root disease would probably be non-existent.

A special case in point may be mentioned here. Tapioca was extensively cultivated before the rubber era in certain districts in Malacca and Kedah. These old tapioca areas were allowed to become derelict, in some cases for many years, after being abandoned, and they became covered with a heavy, coarse growth of "lallang" grass (*Imperata arundinacea*, Cyrillo). Many of these areas were later planted up with rubber, and usually there were few signs of jungle stumps or timber remaining when the work was put in hand. Some of the estates in the Malacca district are large properties, and practically no reports of root disease have ever emanated from those opened up on "lallang" land. It is a well-known fact that a vigorous growth of *Fomes lignosus* is often found on tubers of Tapioca, but it does not seem to do a great amount of harm to them. If rubber had been planted directly following the Tapioca crop, there is little doubt that white-root disease would have appeared; but a long enough period having been allowed to elapse when the conditions were unfavourable to the development of the fungus, the disease was conspicuous by its absence.

The foregoing remarks apply to rubber plantations in Ceylon, commenced on old coffee land. This crop was going strong in 1870. Rubber-planting became a general proposition in the Middle East in the decade 1900–1910, so that there was ample time for the total disappearance by natural decay of jungle stumps and timber from old coffee areas.

In Malaya, during recent years, attention has been directed to the fact that small-holdings apparently show far less root disease than the large estates under European supervision. This has led to considerable correspondence as to the merits of Native *versus* European planting methods. Such a controversial matter cannot be dwelt upon at length in this book, but the statement has repeatedly been made by the writer that there is no doubt that patches of red-root disease can be commonly found in small rubber holdings under native control. The view has never gained full acceptance and has been ignored entirely by ardent supporters of forestry methods. Up to 1934, little reliable evidence could be produced in support of the view; it was a statement based on personal experience in the country. The most recent official announcement, however, from Malaya, is made by the Economics Branch of the Department of Agriculture, on *Small Rubber Holdings in 1934*, and this report states, *inter alia*:

> In Perak, persistent reports of damage by root disease were received which will receive further investigation; there would seem to be little doubt that in some localities, root disease—probably mainly *Ganoderma pseudoferreum*—is more prevalent in small holdings than has been supposed to be the case.

Further evidence for the view that root diseases are common in native rubber holdings can be quoted as coming from Java, for Leefman wrote in 1933 as follows:

> that owing to the prevalence of bark and root diseases, 20%–30% of the *Hevea* rubber trees in the older *native* plantations in the Tapanoeli Residency, in Java, have become unproductive.

The evidence for the writer's views, given above, strongly emphasises the suggestion that the differences in the prevalence of root diseases in native small-holdings and European estates will eventually be found to be more apparent than real. Asiatic small-holdings are usually opened on land which has previously been planted up with trees not susceptible to red-root disease. As the fungus will die out in course of time if susceptible trees are absent, there are very few signs of red-root rot in mature trees growing in native holdings. Numbers of rubber trees are often planted up in *kampongs* (native gardens), which usually carry a mixture of fruit trees, coconut palms, etc. The only common fruit tree recorded as being susceptible to *Ganoderma pseudoferreum* is the Durian (*Durio zibethinus*, Murr.), and if rubber trees were planted intermixed with durian trees, there is little doubt that red-root disease would be commonly found. The

above remarks must be taken as applying only to Asiatic smallholdings in Malaya.

The next point for consideration is the status of *Rhizoctonia bataticola* (Taub.), Butler, as a causal agent of root disease of rubber trees in Malaya.

Root Diseases of Rubber in Malaya and Rhizoctonia bataticola (Taub.), Butler

Exceedingly wide claims were made by Small to the effect that *R. bataticola* was the cause of root disease of plantation crops in Ceylon. The crops specially mentioned by him were "two plants of great economic importance in Ceylon, namely, Tea and Rubber". The fungi mentioned by this investigator as being under suspicion are the following:

(*a*) *Fomes lignosus*
(*b*) *Fomes lamaoensis*
(*c*) *Ustulina*
(*d*) *Poria*
(*e*) *Rosellinia*
(*f*) *Diplodia*

No good purpose will be served by stirring up the pool of dissension created by Small's articles; this now seems to have settled down, and for the time being a smooth surface is showing. The writer feels justified in alluding to the subject only in so far as the root diseases of rubber in Malaya are concerned.

Small's claims were that the fungi, formerly considered to be the cause of the important root diseases of rubber and tea, were only of secondary importance. The basis of this statement rested on the discovery made by Small of the presence of *R. bataticola* in diseased rubber and tea roots, and in most cases one of the fungi mentioned in the above list was also present. He considered that, in all cases where *R. bataticola* was found, this fungus must be considered to be of primary importance, though he admits that "in the absence of the results of inoculation experiments there is a certain amount of conjecture which is unavoidable at the moment". Small's attitude is perhaps best indicated by the following short extract from his first article on this subject:

> I therefore continue to regard all the plants involved in an outbreak of root disease, whether large or small, as having been attacked in the first place by *Rhizoctonia bataticola*, and I hold that trenching and stumping are of little, if any, value as treatment of the outbreak because they do not affect in any way the incidence of the spread of the *Rhizoctonia*, a fungus which does not move from plant to plant by contact, does not

spread through the soil by creeping mycelium and is widely distributed in Ceylon soils.

It appears, therefore, that if evidence can be produced to show that the important root diseases of rubber trees do spread by contact in Malaya, Small's views may be considered of little importance in connection with the root-disease problems encountered in that country. Overwhelming evidence has already been given to show that the diseases caused by *Fomes lignosus* and *Ganoderma pseudoferreum* in Malayan rubber plantations do spread by contact.

No evidence has been obtained over the last three years to support the claims of Small in relation to rubber diseases, either in Java or Malaya. Even if the evidence provided by the illustrations in the text is alone considered, no doubt can exist in the mind of any practised observer in Malaya that the two important fungi causing root diseases spread by root-contact. In the case of white-root disease, Napper has carefully dug out hundreds of cases of diseased trees, and in every case, without exception, the source of infection has proved to be a jungle stump or a piece of jungle timber, the latter often of small dimensions, which is being rotted away by *F. lignosus*. *R. bataticola* was never found, though a close examination for this fungus was always made. The difficulties attendant on this comprehensive field-work were enormous, for the soil had occasionally to be dug out to a depth of four feet, in a circle round a tree, with a radius of fifteen feet or more. However, the evidence secured is so convincing, that full compensation for the hard labour involved was obtained. There is not the slightest doubt remaining that the root disease caused by *F. lignosus* spreads by root-contact, once the roots of the neighbouring rubber trees have grown sufficiently long to come into contact with infected jungle timber or with roots of a diseased tree.

With reference to *G. pseudoferreum*, any investigator who has worked in a diseased field of mature rubber in Malaya cannot possibly come to any other than the same conclusion. When a large, badly diseased lateral root is followed up to its outward extremity, it will usually be found to come into close contact at various points with lightly affected roots belonging to other trees. If these roots are examined carefully at the point of contact, it is obvious that the earliest infection is made at these points, for the whole of the tissues of the lightly affected roots are here involved; the fungus then spreads along the root in both directions with the amount of diseased tissue gradually decreasing as a greater distance is passed from the point of contact, until finally the diseased tissue cannot be found at all. This method of infection and spread is such a commonplace feature

that it is quite unnecessary to postulate the presence of another fungus.

The only possible conclusion to be drawn is that, in Malaya, the two most important root diseases spread by root-contact. Further, no evidence has been obtained to indicate that *R. bataticola* is associated with these root diseases either in a primary or even a secondary capacity.

There are other matters which might be commented upon. The writer is of the opinion that Small's discovery of *R. bataticola* on diseased roots of rubber and tea is of the greatest interest, but the finding of this fungus in Ceylon is no more surprising to Malayan and Javan investigators than the complete absence of *Ganoderma pseudo-ferreum* in that country on mature rubber. An attempt to account for fundamental differences such as these, which are evident in different countries, should be made, and a tentative explanation is given above. With respect to Small's reference to trenching methods being of little, if any, value as treatment (in control of root diseases), the recent work in Malaya indicates that, in the early stages of the plantation, there may be some truth in this statement; but later, when spread by root-contact between neighbouring trees becomes effective, the immense value of trenching immediately becomes obvious.

Replanting of old Diseased Areas in Malaya

It is only to be expected that, during the prosperous periods of the past, rubber estates with available jungle reserves would endeavour to bring them into the profitable bearing stage. For this reason, the majority of old estates in Malaya have at the present day no jungle reserve land available. Further, the allotment of areas of jungle reserve for the purpose of planting rubber has been officially prohibited in the three states where the rubber plantation industry has been most extensively developed. Numerous estates on which red-root disease on the old rubber areas has been allowed to develop without restriction, now possess areas of rubber which have become uneconomic units owing to disease, and if it is wished to place these areas in the economic list once again, they are practically forced to consider replanting. The re-conditioning of the soil of such blocks of land for the purpose of rubber-planting is more expensive than the felling of jungle and planting-up on virgin soil, and the ensuing results might be expected to be more problematical. There are two reasons for this:

(*a*) The areas to be replanted have carried badly diseased trees,

and the soil must be considered to be riddled with infective material (mainly diseased rubber roots); if the prospects of successful replanting are to be ensured, this must be totally removed as far as possible.

(*b*) The soil which has been under cultivation with rubber for a period between twenty and thirty years may be expected to be in a comparatively exhausted condition, for during their period of growth rubber trees are continuously drawing on the nutritive material present, and comparatively little return of organic material to the soil is made in the way of leaf-fall, etc. It might be worth stating here that the soil of rubber estates in Malaya may be considered definitely poor in nutritive materials from the outset, and at the end of twenty to thirty years' growth its condition must have become decidedly worse.

Under these conditions, we may justly enquire why, during depressed financial periods, a policy of replanting uneconomic areas should be undertaken. The reply is found in the probable yields of rubber to be obtained by utilising modern methods of planting-up bud-grafted material, i.e. trees which have been proved definitely superior and found to possess all the desirable properties. These strains of rubber trees are expected to give greatly increased yields, even to the extent of twice or three times the amount given by the ordinary mixed material planted in past years. The writer has stated on more than one occasion in the past, that if only the question of increased yields from bud-grafted material can be confirmed by the production of sufficient credible evidence, it seems only a matter of time before a bud-grafting policy will be forced on all rubber estates which have reserve funds available. The time does not seem far distant when estates with an eye to the future will be utilising the modern methods of bud-grafting to the full, in spite of the recent introduction of restriction which, incidentally, brings rubber into line with most other primary commodities. This modern development is by far the most prominent feature which emerges from all the research work done on the planting side of the industry during recent years.

Reference to the two terms rejuvenation and replanting have already been made, and no further comment is needed. The only policy worth considering in Malaya is replanting, and there is only one distinction to be made, viz. as to whether large or small areas should be dealt with at any particular period. This entirely depends on the question of adequate financial resources.

In view of the extremely favourable reports obtained from bud-grafted areas, the most business-like policy to pursue, if funds are

adequate, is to replant all old areas which are definitely uneconomic, i.e. producing not more than 300 lbs. of rubber per acre per annum. If yields can be doubled, overheads will be halved automatically and costs of production will be largely decreased.

But there are so many estates which show badly diseased patches in their old rubber areas, and a large number of them do not possess adequate monetary reserves to undertake a comprehensive scheme of replanting in large blocks, so some possible alternative recommendation must be made. The only alternative is to concentrate attention on the diseased patches, and to defer work on the healthy areas to a later date.

For estates of limited means, the best scheme for facilitating replanting would be to treat the diseased areas in such a way that any expenditure incurred would be a direct contribution to a more comprehensive scheme. Therefore the work should be designed to clean up any diseased areas in advance of the main replanting scheme, so that when the latter programme is commenced, most of the more strenuous part of the work will have been completed.

Whatever policy is adopted, the treatment of the diseased areas, actually carrying large numbers of diseased trees, should be the same. The tap-roots of diseased trees must be removed to a depth of at least three feet, and all the lateral roots must be extracted as completely as possible. The diseased timber and the remains of the trees, if not required for firewood, must be destroyed by burning *in situ*, if possible; it will be of advantage if the ashes left after burning can be scattered about over the area, in order to utilise the potash content. The soil over badly diseased areas must be dug over to a depth of at least 18 inches, and if any small lateral roots are encountered, they must be gathered and burnt.

The spread by root-contact results in the formation of diseased patches which can be demarcated quite clearly from healthy areas. The clearing work on healthy areas need not receive the meticulous attention which is necessary on diseased areas and the soil need not be dug so deeply: 9–12 ins. will suffice. Thus expenditure on healthy areas should be considerably lower than on diseased ones, owing to the lighter work involved.

Many objections have been raised to the effect that such recommendations would not result in the complete removal from the soil of the infective material. The possibility of a 100 per cent removal being effected is very remote. In the first place, the expense likely to be incurred by adopting such a proposal would be practically prohibitive. An attempt at the complete removal of all the infective timber on

areas which are to be replanted because of root disease would involve digging to a depth of three to four feet and general sifting of the soil. Even when this had been accomplished there could be no guarantee that the desired end had been effected. On one experimental plot three acres in extent, this operation was undertaken at a cost of over 400 dollars per acre. A second drawback which seriously affects the young crop is that deep digging results in considerable disturbance of the infertile subsoil, usually found on Malayan plantations, which is raised to the surface and becomes mixed with the fertile top-soil. As a result of this the young plants make very poor growth. It may seem somewhat remarkable, but it appears that a large proportion of subsoil which is raised remains on the surface, while a large portion of the fertile top-soil becomes buried where it is not readily available until the roots of the young plants have grown considerably in length, and are able to penetrate to lower levels. The setback thus occasioned is very obvious, and, as judged by the above-ground development, it is from twelve months to two years before the plants commence normal growth. The recommendations made above will result in the removal of a good 95 per cent of infective material at a comparatively small cost, and if they can be followed by the systematic treatment for root diseases from the earliest stages, as detailed for *Fomes lignosus* and *Ganoderma pseudoferreum*, there is no reason to fear large losses of expensive planting material owing to outbreaks of root disease, even though a small percentage of infective material still remains in the soil after the main clearing is finished. The detailed report given later will provide all the information required on this point.

It will be perfectly plain to all planters that, if the policy of replanting small patches of badly diseased areas is adopted, an important fact must be kept in mind, viz. each replanted patch must be protected from the competition of the old rubber trees around its boundaries. This applies not only to (*a*) root competition, but also to the equally important factor (*b*), the effect of the shade cast by old rubber trees on the outer rows of trees in the replanted areas. The latter effect is difficult to counteract, and the only recommendation that can be made is that the patches dealt with should be as large as possible, for the larger they are, the smaller will be the proportion of replanted trees affected by the shade. In the writer's opinion, small replanted areas should not be less than ½ an acre in extent, and should be in a square block if possible; a larger sized block would be still more preferable. Many planters have replanted areas not exceeding ⅛ of an acre in size, and claim that good results are likely to ensue. There is little doubt, however, that if the areas are sufficiently large, there are

good prospects for the central portions at any rate producing well-developed trees.

To prevent root competition in small replanted areas, an isolation trench should be preserved at the periphery of the patch. There is no necessity to keep the trench permanently open, but it should not be too strictly limited in size, either in depth or breadth. If it is not kept open, it is necessary to re-dig the trench at intervals, in order to prevent the old trees sending down vigorous, newly developed absorbing roots into the replanted areas.

Whatever policy of replanting is adopted, there remains the question of obtaining the highest possible yields of latex from the standing trees. If a wholesale policy is undertaken over areas not less than ten to twenty acres in extent, as many cuts as will yield latex may be put upon the tree. But where financial exigencies entail a waiting period, it will be dangerous to commence a tapping system which will prove too excessive, for this would lead to considerable trouble from outbreaks of panel diseases, and these must be avoided as far as possible if it is considered desirable to tap the trees for a lengthy but indefinite period. Excessive tapping systems can be used with safety only when the future of the replanting policy can be clearly viewed and the time of commencing is definitely fixed. Systems of excessive tapping can be recommended which will give enormously increased yields, and in Malaya expert advice can always be obtained as to which method of tapping would be most profitable under any particular set of circumstances. On one estate, two years' normal crop of rubber was obtained in six months, the trees giving a yield under the excessive tapping system used, calculated to be at the rate of 1700 lbs. per acre per annum.

Where the soil conditions happen to be unfavourable for the development of rubber trees, disappointment may be met with. This will not be a common occurrence except in areas where the soil has been badly eroded in the past. But the soil in any area which has supported rubber trees for the past twenty to thirty years cannot be expected to compare in suitability with the soil ready for use in newly felled jungle areas. Therefore, immediate steps must be taken to improve soil conditions by planting of cover-crops, etc., for it is of primary importance in starting replanted areas; if a suitable cover-crop can be easily established it can be taken for granted that the replanting will be successful. During the first four years, enough light will be available for the successful working of cover-crops, and periodical turning-in of green material will result in some soil improvement.

Even, however, if a cover-crop is established successfully, on soil

which seems not unsuitable for rubber-growing, the young trees may appear to develop well in the early stages, but later show a very definite lag in growth. The only manner of surmounting this is by the use of inorganic, chemical manures. In fact, chemical manures are likely to become of the greatest importance in the successful development of replanted areas, for it is very doubtful whether normal growth can be maintained in the early years by a green cover-crop only. Further, if the high yields of latex are to be obtained, as anticipated, they can only be kept up by utilising larger amounts of nutritive materials from the soil than did the previous trees, and some compensation must be made to the soil for this continuous drain. In the writer's opinion, this will be done only by the working out of a complete manurial scheme in which chemicals will play the chief part.

The following scheme is taken from an estate report signed by R. P. N. Napper:

In the planting hole .	4 oz. per tree	Young Rubber Mixture
After 6 months . .	3 oz. ,,	,, ,,
,, 1 year . .	8 oz. ,,	Enpekay
,, 2 years . .	1 lb. ,,	,,
,, 3 years . .	1½ lb. ,,	Sulphate of Ammonia
,, 4 years . .	2 lbs. ,,	,, ,,

He adds further:

Permanent improvement in soil conditions can be taken in hand by encouraging the growth of a natural or planted shrubby cover between the rows. A legume like Lamtoro (*Leucaena glauca*) or Tephrosia, would probably require assistance with a fertiliser at the start, and for this reason a natural cover might be preferred. The planting rows should be kept clean-weeded up to 7–8 feet width, to minimise the competition between the cover and the young rubber trees. Fertilisers intended specifically for the rubber trees should be applied only within the limit of those clean-weeded rentices and maximum benefit will be obtained if they are restricted to a circle, or rather to a ring around each tree, coinciding with the main absorbing area of its root system. These rings will of course expand as the trees increase their root range, and should be estimated at each application.

The writer agrees with this advice in the main, but would add the following remarks, merely to express personal preference. The seeds or the cuttings of a green cover-crop should be inserted as soon as possible in all places where clearing has been finally accomplished. Immediately the cover-crop shows signs of successful development, the stumps or seeds of the rubber plants can be planted, but if the soil conditions prevent the initial successful growth of the cover-crop, then it is more than likely that the young rubber plants will suffer

adversely. The best criterion for judging whether the soil conditions over a replanted area are suitable for the planting of the young rubber plants appears to be the success or otherwise of the cover-crop, and planting-up should not be attempted until definite signs of success are obtained. Bushy covers, such as suggested, could no doubt be used in conjunction with a green cover with very satisfactory results, but the suggestion to use natural covers does not meet with the writer's present approval. It is admitted that the development of natural covers must be considered haphazard and therefore somewhat unscientific, although an enthusiast might make even a comparative success along these lines. But the future developments in rubber planting will necessitate the abolition of haphazard methods.

In concluding this portion on replanting, the writer would mention that little has been heard of the recent activities in this line. However, reports of the annual general meetings of two important rubber companies appeared in the *Malay Weekly Mail* dated May 23rd, 1935. Definite references to "future policy" were contained in these reports. The portion dealing with a programme of replanting on one estate is reproduced below, and it seems clear that the methods recommended herein are being taken into serious consideration.

> Turning to the question of our policy for the future, the board is investigating the advisability of embarking upon a programme of replanting, with a view gradually to replacing our older areas with bud-grafted rubber.
>
> The extent of such a programme is limited by enactment to a total of 20 per cent of one's planted area, during such period as rubber regulation may remain in force; but, in any case, the board's views are that the question should be tackled gradually and that no larger programme should at present be embarked upon than can be comfortably financed from our existing reserves.

When any particular problem is under review, it is always of interest to compare the position in Malaya with that existing in other rubber-growing countries in the Middle East. An article was published by E. von Zboray in 1930, and the extracts clearly indicate that, with reference to the close interdependence between the red-root disease caused by *Ganoderma pseudoferreum* and replanting of old areas on estates which have no reserve jungle areas available for new planting, the position in Java is exactly the same as in Malaya. Readers will appreciate many minor points of difference, but this does not require comment, for much progress can be recorded since the article was written. The points of agreement on the major issues are so obvious, however, that they must be considered to hold the greatest significance.

The writer states, *inter alia*:

Among the many rubber problems still unsolved, the red-root rot takes a very forward place. I doubt if in the present slump in rubber there are many more important problems waiting for solution than the combating of one rot or another. A problem that is always cropping up is: What must we do with our fields to make them pay? Other tapping systems, more trees per acre, tap to death our present plantations and replace them by better material by re-clearing or rejuvenating; or is the solution to be sought elsewhere? Naturally everyone would have as good producers as possible on his estate. Unfortunately old plantations are in very many instances giving only a very moderate yield or are going back. Everyone, then, is busily transforming poor fields into valuable high-yielding gardens. In places where there is no root disease, replanting requires no particular care. But where the soil is infected with root disease, it is a much more difficult question. We have here to deal with a great unknown problem. For it is not yet known how soon the red-root disease (*Ganoderma pseudo-ferreum*) attacks newly planted trees nor can we say with certainty how long a time a tree, attacked by red-root disease, takes to die.

In practice it is impossible to make soil infected with red-root disease entirely free from timber in re-clearing. In Bantan, an original clearing from which all rubber was removed to a depth of one metre, cost 400 guilders per bouw (nearly dollars Straits 150 per acre). Notwithstanding this high cost, it still cannot be said definitely that there is not a stick of timber left in the ground to become a source of infection later.

It is thus an outstanding question whether soils where root disease is present, can be completely cleared of timber or rendered sterile before new rubber is planted. For this question to be answered definitely, we must first know how a rubber tree does in infected soil.

It is known that young plantations suffer from white-root disease; however it is usually not so bad, and after some treatment the percentage of trees attacked falls and as the trees grow older the disease completely disappears. Red-root disease on the other hand is considered to be a disease of old plantations. But what happens to the red-root disease in young plantations, and similarly in re-clearing works?

Following on the above, the writer gives details to prove that five years after planting rubber trees in soil areas which had carried old trees suffering from red-root disease, they had become infected with the same disease. He goes on to state:

Within five years after the attack, the trees die off. There may be hundreds of infection centres in infected soil, from which it is theoretically possible that all trees planted are destroyed within five years. The danger of red-root rot in re-cleared gardens is thus not illusory, and it is very possible that just at the time the trees become tapable, a number of them will die off. How big the wastage will be naturally depends upon very many factors—the number of infection centres left in the ground, the thickness of the stand of plants, growth conditions of the disease, etc.

I think this shows quite emphatically that in re-clearing or rejuvenating the soil ought to be purified of all possible root-remains. Eventually the soil must be disinfected by chemical means. Although costs are now so high, this money must be spent, unless we are to run the risk of finding in five years' time the plantation dead as it stands.

Conclusion.—From the above facts the conclusion may be drawn that young *Hevea* trees under certain circumstances may die off of this disease.

Whether under conditions more favourable to the disease the process will run its course in a shorter time still, is naturally not ruled out. The converse is also possible, namely, that an affected *Hevea* tree may offer resistance for longer than five years.

The fact that an affected tree can die within five years demands the greatest care in re-clearing or rejuvenating of old plantations where red-root rot prevails.

Costs of Replanting on old Rubber Areas

Costs of replanting vary according to locality. One estate favourably situated has replanted one area at a nominal cost, by arranging that all the felled timber could be taken away for sale in exchange for the labour required to undertake the preliminaries of felling, digging of soil, collection of all timber, etc. etc., and the manager calculates that the only cost to the company will amount to not more than 30 dollars per acre. The schedules given, however, will enable planters to estimate what prices should be paid for the work in their own particular districts, when let out on contract to Chinese contractors. The work is very heavy and Chinese seems more suitable than Tamil labour. Schedule (A) gives itemised costs for replanting small, vacant spaces, and Schedule (B) gives the same items in a more detailed form, for replanting in a wholesale manner over a large acreage. It will be noticed here that fifteen acres have been felled and cleared free of cost.

Schedule (A)

Cost of replanting Vacant Spaces

		$ c.
(1)	Felling and removing tap-roots to a depth of 3 feet and burning, 55 trees per acre @ 40 cents . .	22.00
(2)	Chengkolling to a depth of 18 inches and removing all timber and roots and burning same, per acre .	30.00
(3)	Holing, Filling (size of hole $2\frac{1}{2}$ ft. deep by 3 ft.) $16' \times 17' = 160$ trees per acre @ $2\frac{1}{2}$ cents	4.00
(4)	Planting budded stumps (own budwood), 160 @ 4 cents	6.40
(5)	Contour drains 15 chains to an acre (size of drains 2 ft. by 2 ft.) @ 50 cents per chain	7.50
	Total per acre . .	$69.90

SCHEDULE (B)

Cost of replanting 30 *Acres of Old Rubber*

	$ c.
FELLING	
Felling and clearing timber on 15 acres free of cost; timber being given in lieu of payment	Nil.
Felling and burning timber on 15 acres @ 70 cents per tree (645 trees)	451.50
Broadcasting ash	1.47
Pruning overhanging branches of trees along boundary	19.47
2 Trewhella jacks	664.00
Transport and repairs to jacks	31.08
	$1167.52

	$ c.
DIGGING	
Digging over 30 acres @ $30 per acre	900.00
Digging over diseased patches and old bungalow compound—second time—and breaking up the cement floor of the old bungalow	164.54
	$1064.54

	$ c.
LINING	
Lining 30 acres 18′ × 18′ × 18′ (triangular)	43.94
HOLING	
4415 holes @ 2 cents each	88.30
Extra payment on laterite area	.70
	$89.00

		$ c.
PLANTING		
Digging out stumps from nursery, transport and planting		77.67
COVER-CROPS		
Sowing mixture of *Centrosema pubescens* and *Calopogonium* at the rate of 4 lbs. of each per acre—cost of seeds and labour		26.67
DRAINING		
Digging deep water drains and deepening existing drains and outlet drains		217.96
BUDDING	$ c.	
Entwax	15.32	
Budding cloth	42.90	
Budding labour—7627 stumps @ 2 cents each	152.54	
Preparing cloth @ 50 per piece	6.50	
Cutting budwood	5.00	

Identification posts for clone numbers	$ c. 34.50	
Painting asphaltum . . .	3.67	
Bamboo shields for budded stumps in field	22.60	$ c.
		283.03
Fencing		
With jungle timber posts 10 ft. apart and wire netting with a line barbed wire at top and bottom		94.17
Weeding		
One round @ $1.50		45.00
Total . . .		$3509.18
Cost per acre		$116.97

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SECTION 2

TAPPING PANEL AFFECTIONS

CHAPTER XI

MAJOR DISEASES

Mouldy Rot—Brown Bast

Introduction

At the present date, four major diseases of the tapping panel are recognised and they are listed below in the order of their importance, in Malaya.

	Common Name		*Causal Fungus*
(1)	Mouldy Rot.	Caused by	*Ceratostomella fimbriata* (E. & H.), Elliot = *Sphaeronema fimbriatum* (E. & H.), Sacc.
(2)	Brown Bast.	Cause,	Physiological
(3)	Black Stripe.	Caused by	*Phytophthora palmivora*, Butler = *Phytophthora faberi*, Maubl.
(4)	Patch Canker.	Caused by	*Pythium complectens*, Braun.

From 1912 to 1920, black stripe and patch canker were considered to be the most important panel diseases. Up till 1918, there was some confusion in respect of numbers (2), (3) and (4) owing to earlier observations by Rutgers, who concluded that brown-bast symptoms were also caused by the fungus causing black stripe. Pratt, in Sumatra, was the first observer to register brown bast as an entirely separate disease.

Despite Rutgers' assertions to the contrary, it may be taken as correct that, except for a slight outbreak of some bark affection in 1910–11, rubber trees in Malaya were, as a whole, free from *Phytophthora* bark diseases till 1916. In the latter half of 1916, which was an unusually wet period, two serious outbreaks of panel disease occurred in widely separated localities: (*a*) black stripe in North Perak, (*b*) mouldy rot in Negri Sembilan. The former soon became generally distributed, but the latter remained for some considerable time

closely confined to Negri Sembilan. During the last six to eight years, however, mouldy rot has spread practically throughout Malaya, and at the present time it is by far the most important panel disease in the country.

Brown bast suddenly sprang into prominence during 1918, and from that year onwards till 1922 caused great alarm. About the year 1922, sufficient evidence had been collected to show that exhaustive tapping exercised a considerable influence on the causation and spread of the disease. In districts where daily tapping was the rule, the percentage affection was often high, but on reverting to an alternate daily system, the number of brown-bast cases was greatly reduced.

Mouldy Rot

Caused by *Ceratostomella fimbriata* (E. & H.), Elliot
= *Sphaeronema fimbriatum* (E. & H.), Sacc.

Mouldy rot disease was first definitely reported in Malaya in the latter part of the year 1916. An earlier record exists of a fungus growing over the surface of the tapped bark of some rubber trees on a plantation near Kuala Pilah in 1915, but it states that the fungus did not appear to be causing damage. As this district is not far separated from Seremban, where mouldy rot first definitely appeared in 1917, and as there is considerable reason to believe that the fungus causing mouldy rot has increased in virulence with the passage of time, the 1915 note may very possibly have been the first actual record of the disease. In Java the disease was first found in 1920 and was reported to be rather virulent in Mid-Java. It has not yet been reported from Ceylon or India.

Mouldy rot is by far the most serious tapping panel disease in Malaya. Up to date, there is no information to show how it originated. Its first occurrence in one definite and limited area suggests that the fungus may have been imported on another host plant and may have spread from it to the tapping panels of rubber trees. If the fungus was originally native to the peninsula, living on one or more different hosts, and if it had spread from these and become adapted to living as a wound parasite on the tapped bark of rubber trees, such adaptation would probably have occurred in more than one locality at about the same time. It is fairly certain, however, that the disease spread from the one originally infected area and was conveyed to other localities, mainly by human agency.

The details with respect to the spread of mouldy rot throughout Malaya have been given for the years 1917–24 by South and Sharples,

and in later years spread has been continuous, so that there are few rubber-growing districts to which it has not gained access. The writer has constantly pointed out its dangerous nature, more especially in view of the possibility of a more virulent strain of the fungus developing. In 1925 attention was called to the fact that more virulent attacks might be anticipated, for while in 1916–17 the fungus was seldom seen within ½ inch of the tapping cut, i.e. it took ten to twelve days to develop the typical visible symptoms, at the end of 1918 disease spots appeared less than ¼ inch above the tapping cut, i.e. five days or even less had sufficed for the symptoms to become visible on the surface of the renewing bark. At the present date there is not the slightest doubt that, in certain districts, treatment which has been successfully employed since 1922 is not now keeping the fungus under control as formerly; and, as explained below, the fungus, in nature, now seldom produces the perithecial forms of fructification as it used to in 1917–20. The main fact which has adversely influenced the position is the lack of funds for disease work during the last two or three years of the last rubber slump. On Asiatic holdings, daily tapping has been carried out on infected trees without any attempt being made towards treatment, and even on European estates, European staff has been severely reduced and lack of essential supervision naturally follows.

Symptoms.—The earliest signs of an attack of mouldy rot are depressed spots or blotches from ¼ to 1 inch above the tapping cut which spread and join up to form an irregular, depressed band parallel to the cut. The diseased tissues rapidly darken and become covered with a thick, greyish mould easily visible at a considerable distance, say 30 to 40 yards, consisting of a mixture of fungi, chiefly mycelium and spores of *Ceratostomella fimbriata* (E. & H.), Elliot, and a *Cephalosporium* sp. This mould is the most characteristic feature of the disease, and once seen cannot be mistaken for anything else (Plate III and Fig. 26). In a later stage, small black bristles, about 0·5 mm. long, may be found rising through the mould (this relates to the years 1916–21). These are the necks of the perithecia of the *Ceratostomella* shape, to which wax-like masses of spores are found attached. It is only comparatively recently that the spores of this fungus were found to be true ascus-spores with 8 spores in each ascus; the asci are very numerous and are enclosed in the flask-shaped perithecium which has a long beak and fimbriated opening (Fig. 29). Before extrusion the walls of the asci break down and the individual spores become free in the cavity of the perithecium; later they are extruded and remain attached to the fimbriated tips of the pycnidia

as the wax-like masses referred to above.

Under favourable conditions, perithecia were produced in immense numbers in past years, many hundreds being found crowded together in a very small bark area. Their production was a constant feature up till 1920, for in this year Sanderson and Sutcliffe reported that "the pycnidium (perithecium) is quite characteristic and should always be looked for in supposed cases of mouldy rot". The perithecial fructifications have been seen but rarely during the last two years, and it appears that, in nature, perithecial development is now in abeyance in Malaya. This feature was noticeable about 1925–26 and it has been confirmed over the last few years, for very few cases have been found in spite of intensive searching.

FIG. 26.—Mouldy rot. Photograph of tree showing surface mould on tapping panel. The two vertical lines on trunk are internal bark fissures (p. 260).

In three to four weeks after infection the diseased tissues rot completely, exposing diseased and discoloured wood and forming wounds similar to those produced by bad tapping (Fig. 27 *a*, *b*). Penetration of the wood is slight and wood discoloration is rarely found at a depth exceeding ¼ inch. It may be greenish-black in colour. The fungus has never been found to penetrate below the tapping cut, although narrow dark hair lines may run in the wood above and below the cut. They are both narrower and darker than the lines seen in black-stripe disease caused by *Phytophthora*, which also affects the tapped areas. Similar but shorter lines may not infrequently be found running from ordinary tapping wounds.

While continuous rainfall or damp weather is essential for epidemic spread of mouldy rot, it appeared in 1916 that the disease could not develop seriously unless other conditions, either favourable to the fungus or unfavourable to the rubber trees, obtained. In recent years,

however, it has been found that the disease may appear in virulent form on estates run on model lines.

The Fungus.—When the disease first appeared it was thought that some species of *Phytophthora* was the cause of the trouble; but this has never been found, and inoculation experiments showed that *Ceratostomella fimbriata* was capable of reproducing the disease.

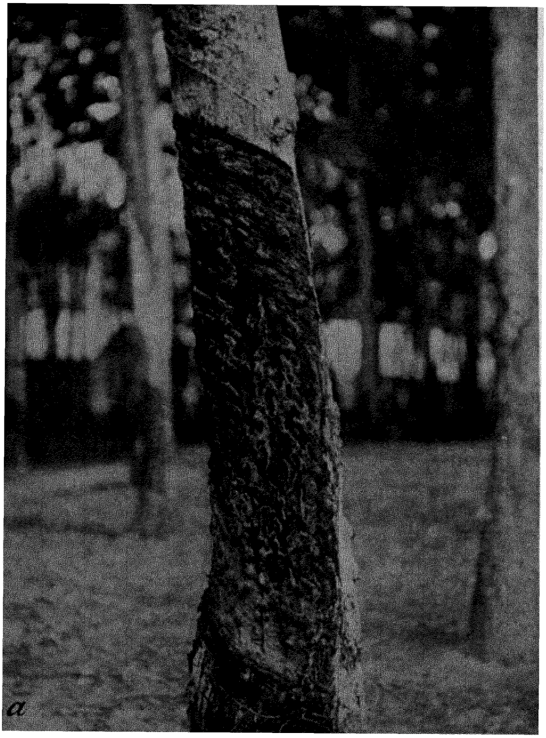


FIG. 27 *a*.—Mouldy rot. Photograph of tree in native holding which has been affected by mouldy rot for a long time and left untreated.

C. fimbriata possesses three distinct spore forms: ascospores, borne in and extruded from flask-shaped perithecia; and two kinds of endospores—one, hyaline and thin-walled, the other dark coloured and thick-walled. Following Halstead and Fairchild,[1] these two types of endospores will be called hyaline endoconidia and macrospores respectively.

[1] *Bull. No. 76, N. Jersey Agric. Station*, p. 14.

The external mycelium of *C. fimbriata* is composed of septate, lightly coloured hyphae, 3–5μ broad, often containing oil-drops. Hyaline endoconidia are found in abundance in the surface mould on diseased bark and are cylindrical, and often loosely attached by their ends to form chains. They are variable in size from 16–31 × 8·0 to 6·5μ, and average 20·8 × 5·3μ (Fig. 28). Their method of produc-

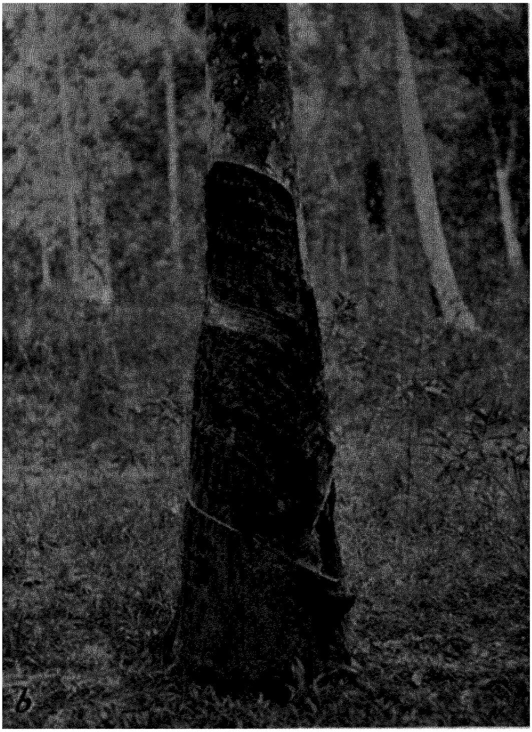


FIG. 27 *b*.—Mouldy rot. Photograph of tree in native holding which has been affected by mouldy rot for a long time and left untreated.

tion can rarely be seen in such material, and is best seen in culture. Macrospores are also produced on the surface, but are few in number compared with the profusion of hyaline spores. They are continuous, generally spherical to elliptical, often with short stalk-like protrusions at one or both ends; a few aberrant forms may be cylindrical. They are generally olive-brown, and have well-marked, thick walls, and frequently two to three large oil-drops (Fig. 28, C).

In size they range from 13·6 to 22·2 × 12·2 to 13·8μ, with an average of 15·9 × 13·1μ. Perithecia are gregarious, black, with a thin, basal

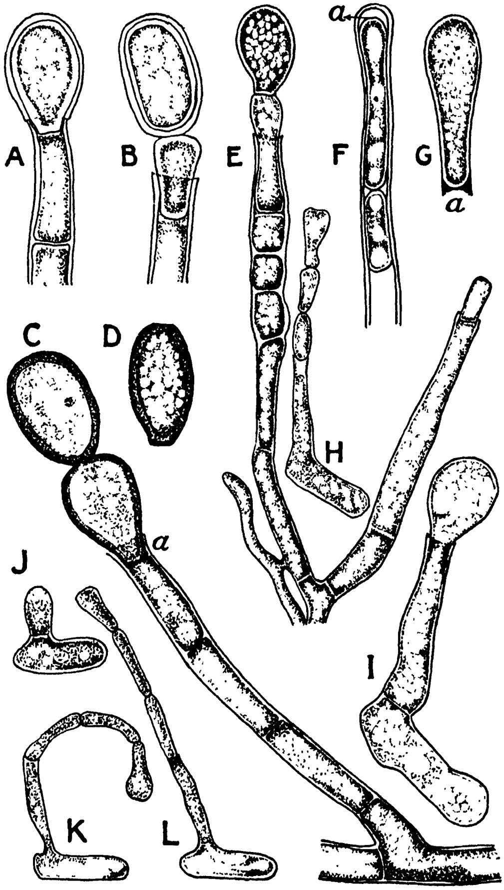


FIG. 28.—*Ceratostomella fimbriata*. (After Andrews and Harter.)

A-D, Olive-brown thick-walled conidia. × 1000. A and B indicate that the first abstricted spore is double walled; spores produced later from the same conidiophore are single walled.
E-L, Hyaline conidia.
E, Conidiophore showing hyphal fusion at its base. × 666.
F, Separation of the spore wall from the conidiophore end wall at *a* as a result of plasmolysis. × 1000
G, Probably a remnant of the middle lamella *a* shown at base of recently abstricted spore. × 666.
H, I, Germinated spores forming new endoconidia. × 666.
J, Early stage in germination. × 666.
K, L, Evacuation of spore contents after germination; contrast with H. × 666.
A-D and F, from stained sections, others from live material.

bulbous portion, about three parts immersed in the bark tissues. They vary from 300 to 500μ in length; diameter of the basal bulb 50–100μ. The perithecial necks are long, about four times the dia-

meter of the bulb, therefore varying in length from 200 to 400μ; width of neck 26μ, tapering to 15μ. Ascospores vary from 4·5 to 8·7 × 3·5 to 4·7μ (Fig. 29).

When grown in culture the necks of the perithecia appear to be even more variable in size. Dr. S. F. Ashby received cultures from Malaya and recorded measurements of 300–700μ; in another case they were up to 1 mm. in length, while the fungus, isolated from sweet-potato in Trinidad, produced perithecia with necks 400–800μ in length.

When the fungus first came under observation in the field, the slightly tapering perithecial necks looked just like a mass of bristles rising through a tangle of brown mycelium; the fimbriated openings were noticeable because of the hyaline hyphae there.

The production of ascospores has been described. They are hyaline, thin-walled, and vary in shape from spherical to broadly ellipsoidal, often appearing polygonal from mutual pressure. Dr. Ashby informs me that a proportion of the ascospores formed in cultures were annulate.

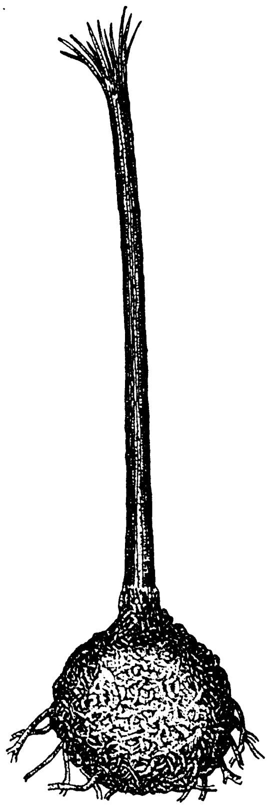


FIG. 29.—Mature perithecium. × 187. (After Andrews and Harter.)

The measurements given were obtained during the investigations being carried through from 1916 to 1918. Since that period numerous investigations have been carried out on this fungus in other countries, and in view of the various new features which have been demonstrated, it seems desirable that further investigation is required into the life history of this fungus in Malaya. The writer commenced work to complete the picture of the life history in 1932, but pressure of other duties precluded much time being spent. There are two other species of *Ceratostomella* found on dead rubber twigs, and enquiries parallel to those on *C. fimbriata* will lead to more reliable information being obtained on the subject generally.

The diseased tissues show microscopically no specially interesting

feature. The hyphae in the bark and wood resemble those on the surface in being septate and branched; they are of a smoky-brown

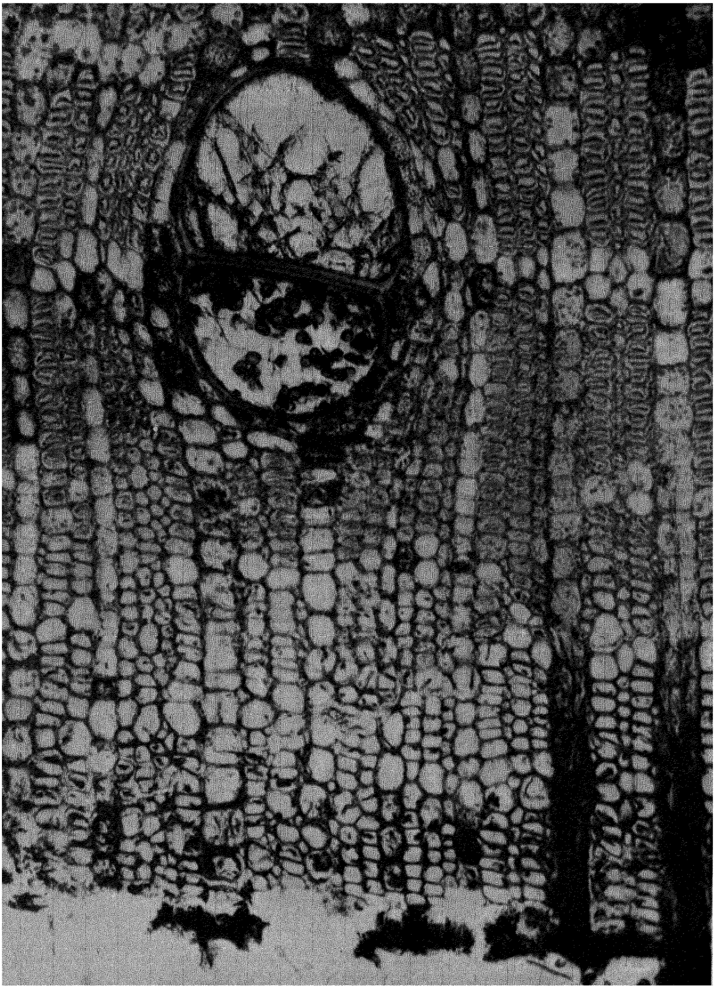


FIG. 30.—Mouldy rot. Section through outer infected area, showing the macrospores developing in the outermost wood vessels. × 333.

colour and intracellular, with no haustoria, and may pass from cell to cell either through pits or by the break-down of the cell walls. Macro-

spores are only rarely found in the tissues, but Fig. 30 shows these spores forming freely in the large wood-vessels at the periphery of the wood cylinder, and such a feature may account for the few refractory cases always met with when treatment is undertaken.

In the wood, hyphae are most abundant in the medullary rays, but occur in all the other xylem elements. "Wound gum", dark in colour, is formed in the wood.

Other fungi, chiefly *Cephalosporium* sp. and bacteria, invariably accompany *C. fimbriata* in diseased tissues.

The dark lines running up and down from diseased patches of wood, and described above, are due to the deposition of dark "wound gum" in individual vessels. *C. fimbriata* has never been isolated from these lines, though they are doubtless due to a stimulus derived from its presence. A *Cladosporium* sp. has been obtained, but it was probably a secondary infection, and on inoculation did not reproduce black lines.

Conditions which favour the Onset of the Disease.—(1) Tapping on thin bark, virgin or renewed, where the formation of new healing tissues is slower and the liability to wound is greater. The danger of tapping on poor renewals was well demonstrated on one estate in 1917. Tapping and general conditions were good, except on one patch of about ten acres, near the centre of the estate, where the bark was so thin that tapping should never have been allowed. About 50 per cent of trees were attacked by mouldy rot, while only a few individuals in neighbouring areas were affected. Soil conditions appeared to be uniform.

(2) The system of tapping in favour on most of the attacked areas in 1917–18, viz. Chinese labour on contract, also lends itself to the spread of the disease. Naturally the contract tapper tends to work for maximum latex yield and taps deeply, wounding, on the whole, more than a Tamil or other worker on daily wages. The tapping on native holdings follows much the same opportunist policy with similar results. Exceptions can of course be found. One affected estate in 1916–17 employed Tamil labour, while another conspicuously immune, though in the very worst infected area, was on Chinese contract.

(3) Any factor maintaining high humidity around the tapping panels will encourage the disease. It has only recently been realised that the aerial mycelium of the fungus is very profoundly influenced by external humidity; certain test plots showing a 100 per cent infection on December 24th, 1932, were found to have no visible external symptoms on December 27th, after three days' continuous dry

weather. Thus, dense planting, forestry methods, allowing the "belukar" to develop without hindrance in ravines, will all encourage the growth and spread of the fungus to a degree much greater than has been suspected. On the particular estate where forestry methods were first carried out to the fullest extent, mouldy-rot disease developed on large numbers of trees in the areas where free development of the undergrowth had been allowed, and control of the disease could not be established until the heavy undergrowth had been cut back to ground-level. The bark damage done, while the fungus was active, was enormous and it proved irretrievable, so that there was no doubt that the fungus proved a limiting factor under the conditions provided.

Spore Formation in Pure Culture.—The fungus causing mouldy rot belongs to a small group which produce endospores. The formation of such spores has been mentioned earlier. As already stated, two kinds of endospores are produced, one hyaline endoconidia, the other dark-coloured and thick-walled macrospores. On suitable culture media, and probably in nature, there was, in 1916–17, a definite sequence in spore formation. Within three days of making sub-cultures, an abundance of the thin-walled hyaline endoconidia was produced on the surface of the medium, giving it a powdery appearance; this resembled the first stage appearing on a tapping surface recently infected. Many of the hyaline endoconidia germinate immediately with the formation of a second generation of similar spores. At this stage there is only little hyaline mycelium. About the third day, dark-coloured, short, lateral branches appear and the formation of dark, thick-walled macrospores begins. The whole mycelium gradually darkens and the walls of the hyphae become slightly thicker. After two to three weeks, small black spots, made up of interwoven hyphae, may appear in culture, which develop, in five to seven days, into partially immersed perithecia. These may or may not produce spores. When present, the spores come to form waxy masses at the perithecial mouths, as in nature.

The extrusion of hyaline endoconidia is much more rapid than that of macrospores. The former are pushed out about one every twenty minutes, while the latter appear at the rate of one in five to ten hours.

The germination of the varied spore types only takes place freely in nutrient solutions or culture media. Hyaline endoconidia germinate within twenty-four hours of sowing; macrospores and ascospores germinate in twenty-four to forty-eight hours—the latter after considerable swelling—by the production of a single germ-tube. Andrews and

Harter state that germination of macrospores appears to occur rarely. Once germinated, there is no constant difference between the three spore forms. Very soon after germination, sometimes before any branching has occurred, the production of hyaline endoconidia begins and two or three generations of such spores may be so produced before mycelial growth starts.

The persistence of a fungus in nature depends to a large extent on the resistance of the spores to drying. The ascospores and hyaline endoconidia formed on agar slants have been observed to germinate five weeks after production; macrospores have survived for three months under the same conditions. Resistance to drying has been tested under very rigorous conditions, and while the ascospores and hyaline endoconidia lose their germinating power within twenty-four hours, macrospores resisted drying-out for a period of three weeks. Thus it is obvious that the production of macrospores enables the fungus to withstand very severe drought conditions, and this is the most important spore-form to be considered when discussing the question of control.

When perithecia are present, they arise directly from masses of the dark-coloured mycelium which, with the black perithecia, give the infected surface a black appearance, about ten days after the first appearance of the white mould. As in nature, the long neck of the perithecium has a distinctly striated appearance due to the presence of thicker portions in the form of strands. At the apex, the strands split apart somewhat from the connective tissue, forming the fimbriated mouth through which the masses of ascospores are discharged. The specific name is derived from the fimbriated mouth.

In cultures, development of perithecia and ascospores proceeds just as in nature. When these spores are liberated they adhere to the perithecial mouths as a white, more or less globular, sticky mass, which rapidly turns brown on drying. Eventually the mass of spores is pushed over the side and remains sticking to the outside of the neck, being followed in twenty-four hours or more by a second mass. The masses of ascospores are quickly affected by desiccation, and only a short time after their expulsion they may have lost the power of germination.

Spread and Treatment of Mouldy Rot.—Mouldy rot is a rubber tree disease, peculiar in the fact that its spread to areas far distant is not dependent on the usual atmospheric agencies: transport from one place to another is brought about mainly by human agency. A considerable body of evidence has been collected to support this statement and little doubt remains as to its correctness. Apart from the

evidence as to human agency, it would be difficult to explain how an infection could appear at a place separated by nearly 200 miles from any known source of infection. It should be emphasised that only those spore-forms which are capable of extreme resistance to adverse conditions can be expected successfully to persist through the more or less extended dry period, during their transference to a non-infected area. The spores are carried chiefly on the clothes or tapping knives of coolies, and it seems evident that only the thick-walled macrospores will be able to persist through the adverse period. These are the only ones of the three forms which possess the requisite organisation. Localised spread only can be expected by the dissemination of the wind-spread, thin-walled endospores and ascospores. The particular case is of such exceptional interest that a full description of the method of spread is extracted below, from *Bull. No. 37, Dept. of Ag. S.S. & F.M.S.*

There is some reason for believing that *C. fimbriata* is not one of those fungi which occur commonly in the jungle in this country, but that it is more probable that it was imported in some way. In this respect it differs from the majority of rubber diseases, Pink disease (*Corticium salmonicolor*) and probably even Black Stripe disease (*Phytophthora* sp.). These latter are all caused by fungi that occur on a number of different living or dead plants throughout Malaya and have adapted themselves to living on the rubber tree. Such diseases have naturally occurred fairly generally all over the peninsula at about the same time and are almost universally present, except in localities where certain of the surrounding conditions, especially low humidity, adversely influence their growth. These diseases, in any part of the country, spread to rubber trees, either from decaying jungle timber left on newly cleared estates, or from plants in the surrounding jungle. It follows that the occurrence of any of these diseases on almost any estate is to be expected, and that a few cases of one or more of them can scarcely be avoided. Control measures under such conditions depend mostly on the removal of decaying timber and the prompt treatment of all cases found.

In the case of Mouldy Rot, however, there is good ground for believing that the disease first made its appearance on one estate only and was conveyed from this to a few adjoining estates, probably by Chinese tappers. As has been shown in the previous section on the history of the disease, it spread gradually outward in successive years from the original centre of infection, appearing sporadically here and there in a steadily widening circle. In a number of instances too the new outbreaks have been associated with the presence of tappers known to have been working recently in previously infected localities. Such behaviour is typical of a fungus introduced into the country, that has become adapted to living on the rubber tree. In this connection it may be emphasised that this fungus has never been found in Malaya on any host substance other than the

renewing bark of the rubber tree. Had the disease been due to a fungus widely distributed and growing on various living or dead plants in the jungle, it would almost certainly have adapted itself to rubber in different places at about the same time and, consequently, after appearing in several different localities almost simultaneously, would by now have become almost universally present on rubber estates in the same way as the root diseases and Pink disease have done.

It seems apparent that the methods of spread of Mouldy Rot disease will differ from those of the majority of rubber diseases, since it does not use the jungle for its road as do the others. The question then arises how is it conveyed from place to place, so that it can jump suddenly to an area of rubber separated by many miles from the nearest infected estate without infecting any of the rubber in between. It is noteworthy that, when the disease first appeared at Padang Rengas, in Perak, in December 1922, the affected area was separated by over 200 miles from any known source of infection.

The answer is that in all such cases the disease is conveyed by human agency, tapping coolies carrying the spores of the fungus on their tapping knives, persons and clothes. The disease has been under careful observation in the field for so long and the point is so well established that it seems desirable to give the evidence in some detail, since records of this nature are not numerous.

During the years 1915 to 1917, when the disease first made its appearance and spread rapidly in the State of Negri Sembilan, a number of the large, European-owned estates employed Chinese contractors to tap their trees; there was considerable competition for labour on account of which individual coolies moved about frequently, working first for one contractor and then for another on different estates. It was impossible under the circumstances to keep a close watch on the movements of coolies most of whom were not known personally to the European managers. The conditions in Negri Sembilan were in contrast to those obtaining in other parts of the country, where each estate maintained its own comparatively stationary force of Tamil coolies, most of whom were known to the managers and whose movements, when they occurred, were better known and more easily traced, more especially as it was and is customary to enquire of Tamil coolies recruited locally where they have been working recently. It is clear, therefore, that the labour conditions in the infected area in Negri Sembilan during these years were especially favourable to the spread of the disease by tapping coolies, while the incidence of these conditions corresponded so well with the somewhat rapid spread of the disease in these years from one European estate to another as to afford a clear indication that the movement of tapping coolies was an important factor in this spread. It is noteworthy also that in the first two years of its spread the disease occurred mainly on large European estates, though its subsequent spread was largely on small holdings on which the majority of the attacks occur at the present time.

The impression, which had already been formed, that the disease was mainly spread by human agency was considerably strengthened when the

outbreak occurred at Kuala Pilah towards the end of 1918, at a distance of 20 miles from the nearest infected rubber which was separated from the Kuala Pilah area by a range of jungle-covered hills.

Definite evidence of the presence of a tapper from an infected holding was obtained at Panchor in the Muar district of Johore, when a Malay officer of the Department, sent there to supervise the treatment and control of the disease, recognised a Javanese coolie who had recently been working on an infected holding, belonging to the officer's uncle, in Kuala Pilah district.

Further evidence was again obtained at Padang Rengas in Perak early in 1923. Here the nearest boundary of the large main block of infected holdings, found to be infected at the end of 1922, was about half a mile distant from the main road from Kuala Kangsar to Taiping, the intervening land being partly occupied by a large rubber estate and partly by padi land and fruit orchards. Early in 1923, a few infected holdings were found on the roadside at the 17th mile, a few others were found on the further side of the main road, while yet another infected area of about twenty acres was discovered adjoining an European-owned estate about two miles nearer Taiping. In every case one, or more, of the owners of land in these isolated areas also possessed land in the area first infected; or else, as was the case at the 17th mile, the isolated block of newly attacked trees was on land around the houses of tappers who were employed in the originally infected areas.

An important item in the successful treatment of the disease is the cessation of tapping on all infected small holdings for the period of three weeks, or a month, during which the trees are under treatment. A very large number of such holdings, from 1 to 10 acres in area, are not tapped by their owners, but by coolies of various nationalities, Chinese, Javanese, Banjarese, Tamils or even Malays, who receive half the daily yield of rubber in payment for their work. When tapping is stopped on holdings so worked, the hired tappers immediately leave and go in search of work on other holdings elsewhere. The result is that the necessary measures for the local treatment of the disease are apt to result in its further distribution. Thus, when it appeared at Bruas in December 1923, several Banjarese tappers, working on the infected holdings there, were recognised by the Department's Malay Inspecting Officers as having worked on an infected Chinese estate at Padang Rengas; a week or two later when further infected holdings were discovered at Sungei Rotan on the Bruas–Taiping road, a Banjarese and a Tamil were recognised as having moved on there from the infected holdings at Bruas. Again in September 1924, when the disease appeared at Selama on the Perak–Kedah boundary, a Banjarese family from the infected area at Bruas was found there. In November 1924, two holdings, owned by one man, at Batu Kurau in Perak became infected and a Banjarese was found to be working there who was recognised as formerly employed on the Chinese holding where the disease was first discovered at Padang Rengas.

A point which further supports the spread of this disease by human agency is that in the earlier years, 1915–1921, the spread of the disease

was into Johore and Pahang, localities where labour conditions were difficult and where in consequence the Chinese tapping forces were continually changing.

A further point is that in Malacca, where the disease is present over a large area of small holdings, only five large estates have so far been infected. In this Settlement resident Tamil labour forces are employed on most of the estates. These are settled and contented and are usually recruited with coolies brought direct from India. Consequently the coolies have not come in contact with infection and the estates have remained free from the disease.

On one estate in Malacca, of which one division became infected, it was found that the infected tasks were tapped by Malays who tapped their own diseased trees in the afternoon. On an estate in Perak a few trees became infected beside a path along which passed every day tappers who worked on infected small holdings beyond the estate.

In many instances in recent years, when estates have been infected, the disease has been confined to trees near the boundaries of the estates, where the trees have been liable to be tapped, accidentally or purposely, by the tappers on adjoining infected small holdings. There is, however, in such cases always a possibility that the spores of the fungus may have been carried the few yards from the trees on an infected holding to those on the adjoining estate by wind, driving rain or insects.

The treatment which was worked out in 1917 and amended later in 1922 was based on the fact that there was a definite sequence of spore formation in suitable culture media and therefore probably in nature. The weak point in the life history of the fungus is the thin-walled endospore stage, and if the fungus could be killed in the early stages, before the formation of thick-walled macrospores, it could be kept under adequate control. Thus, if a mouldy-rot infection could be "spotted" before a period of ten days had elapsed, it was very probable that, if treatment was undertaken promptly, all the hyaline endospores, which are very susceptible to injurious agencies, could be destroyed and the attack suppressed.

In practice it was found that a 20 per cent solution of Agrisol, 20 per cent solution of Brunolinum plantarium or a 3 per cent solution of Izal could be used successfully. But one application was not sufficient. The first application reduces the number of diseased cases considerably, but when the treated trees are examined ten days later, numerous cases can still be found, so that a second painting must be given. A second inspection ten days later will probably reveal a further reduction in number, but a few refractory cases will still show signs of the fungus, and so a third painting is necessary. The trees under treatment are put out of tapping for the time being. The following figures were obtained in our experimental work:

Diseased trees before	first painting	. .	948
,, ,,	second ,,	. .	592
,, ,,	third ,,	. .	18

It must be emphasised again that eradication, i.e. complete disappearance, of this disease cannot be hoped for, except at certain periods of the year when the weather is hot and dry for a few consecutive days. The surface mould disappears very rapidly; two to three consecutive days of dry weather is sufficient. A longer period of dry weather may result in the death of the portion of the fungus growing in the host tissues, but this is mainly conjecture. The main point is that control, not eradication, is the only goal we can aim for, even if great care be exercised, and that the most successful method will always show a few refractory and persistent cases of disease.

The method of control described is concisely stated below:

(1) Diseased trees to be put out of tapping for one month.

(2) Solutions of fungicidal disinfectants to be used as in White list given on p. 437.

(3) Three paintings to be given at intervals of ten days.

(4) Ten days to elapse after third painting before recommencing to tap. If the fungus is still showing, further paintings with periods of cessation from tapping must be given.

The cost of controlling mouldy rot by this method over a period of eighteen months worked out, in 1922–23, at 10½ cents per acre per month = $1.26 per acre per annum, and the treatment ensures the bark against injury. There was always a number of mouldy rot cases to be treated at any particular time, but as the number did not increase from month to month, it may be concluded that satisfactory control had been attained.

Since 1929, the position with regard to treatment of mouldy rot cannot be considered to be satisfactory. Over the last three or four years, Asiatic small-holders have not been able to face the diminution in revenue which would result from the cessation of tapping, and for the same reason, daily tapping had to be undertaken. But all the blame cannot be laid at the door of Asiatic small-holders. On European estates, where satisfactory control has been maintained for many years, the management in their quest for economy require the cheapest form of fungicide, and disinfectants with fungicidal properties of proved reliability are superseded by cheaper articles. Further, the European estates which adopt uncontrolled forestry methods will certainly provide encouragement for the mouldy-rot disease. A combination of forest conditions with a period when climate favours the

vigorous development of the fungus would result in rapid and very serious damage being done to the bark reserves of the trees. Under forestry conditions, whether controlled or uncontrolled, the greatest care is necessary once this disease makes its appearance. When it becomes apparent, all undergrowth should be cut back to soil-level and kept low as long as cases of mouldy rot persist.

Another point must be referred to here. The protagonist of forestry methods developed a scheme for control of mouldy rot disease by covering infected bark areas with ordinary whitewash. The explanation given for using an ordinary whitewash was that the use of the alkaline solution would increase the pH value (presumably of the bark areas covered by the solution), and that spores of the fungus causing mouldy rot could not germinate on an alkaline medium. The value of this method of control can be judged from the fact that, on the infected areas so treated, a complete cessation of tapping was ordered by the visiting agent, because bark reserves were practically non-existent. It is evident that whitewash will hide a multitude of defects and, temporarily perhaps make the trees look more decorative, but it has nothing else to recommend it. This matter would not have been referred to here but for the fact that whitewash treatment has been recommended again recently, and it is considered advisable that the planting community should be advised of the results likely to eventuate.

The present general tendency may lead to very dangerous ground. Evidence has been given above for considering that a variant of the former mouldy rot fungus has developed which is more dangerous than the parent form. Further, if tapping, either daily or alternate daily, is continuous, it is exceedingly difficult to check the development of the fungus, and at the present time little attention is paid to any advice which would mean resting diseased trees from tapping for a period of one month. Tests on blocks of trees showing 100 per cent infection have shown that, on trees tapped and painted daily with a water-miscible fungicide, the fungus usually appears to be under control after about ten to twelve daily paintings (Diagram VI). But if painting is stopped at this point, the fungus will re-appear in about five to seven days' time and painting must be resumed. But if a single painting is done every five to seven days after the twelve daily consecutive paintings, it is found that, in a large number of cases, little or no damage is done to the affected bark. Such a method of treatment is expensive on account of the amount of disinfectant used, but as an offset to this there is the amount of latex which is obtained by continuous tapping. The great drawback to

continuous tapping is that affected trees are seldom free from the fungus except during dry-weather periods, and with the slightest degree of carelessness during a period favouring the growth and development of the fungus, an enormous amount of bark damage may

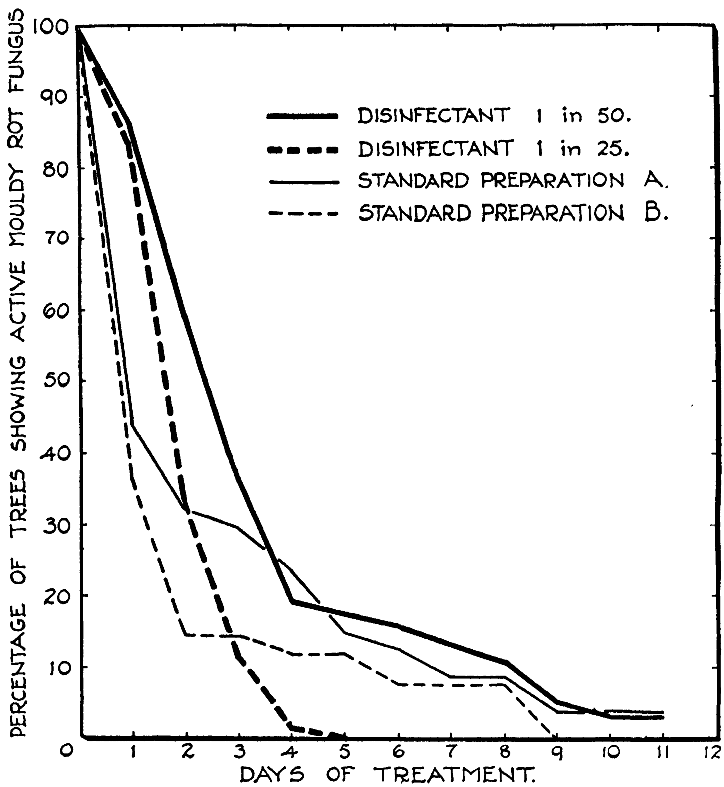


DIAGRAM VI

Curves show results of daily paintings with suitable disinfectant solutions. The number of mouldy rot cases decreases rapidly until the 8th-9th day, when only a small number of barely noticeable cases can be found.

be the result. Although bark damage may be reduced to a minimum while tapping is continued yet control of the disease can never be obtained.

Systems of tapping, involving a period of rest during the year, may be utilised for the purpose of controlling mouldy rot. Thus, in A B C tapping, one-third of the estate is not tapped during four months of

the year. Estates using this system of tapping, which are contiguous to badly infected native holdings, should select their blocks in such a manner that the trees nearest the boundaries and most likely to be infected from the diseased holdings will form the block which will be rested from tapping during the bad mouldy rot months, i.e. from September to December. Very favourable reports have been received from estates adopting this practice.

Precautions of a similar nature may be taken on infected estates where the disease is definitely localised. In such cases a band of healthy trees, 6-12 rows wide or even wider, is formed around the diseased area, and the tapping panels of all the trees in this band are painted with the disinfectant solution in the same manner as the diseased trees, as soon as possible after the latex has been collected.

Dyes such as Methylene Blue and Fuchsin are recommended for colouring the disinfectant solutions with a view to aiding supervision. Red Ochre is often used in various parts of Malaya. The writer is not an ardent supporter of adding dyes to the fungicidal solutions, for if essential supervision is being given it is not difficult to spot whether a tree has been painted or not.

Another point which is often raised, not only by the layman but by trained agricultural officers, is the liability of a water-miscible fungicide to be washed off by rain. I am in full agreement with Steinmann on this point (page 437). The *modus operandi* of a water-miscible fungicide is firstly, that the external mycelium and spores should be killed immediately. Secondly, that enough fungicide should be absorbed by the cortical cells infected by the fungus hyphae as to kill all that may be present. This is a matter of a short time only, if the application is done before the development of the thick-walled macrospores. But if the latter are already in process of formation, numerous paintings are required before they can be killed.

In ordinary circumstances, therefore, the external mycelium and spores are killed almost immediately, and if rain follows, the washing-off of surface fungicide is entirely immaterial. The fungicide absorbed by the cortical cells which are penetrated by the fungus hyphae will be held so tightly that considerable force must be exerted to dissolve this out from the interior of the infected cells, and only an immediate heavy rainstorm would be successful in bringing this about. But most rubber growers are sensible enough to realise that it would be extremely foolish and waste of time and of money if they painted their trees when a rainstorm might be expected soon after painting. The washing-off of surface fungicide should not be considered of ultimate importance, and far too much weight is given to this feature. It has

been shown clearly that repeated applications of the fungicide results in the fungus being overcome fairly rapidly in ten to fourteen days, in spite of daily wet weather which is favourable for the growth of the fungus, and this can only be ascribed to the fungicide being absorbed and strongly held by the affected cortical cells.

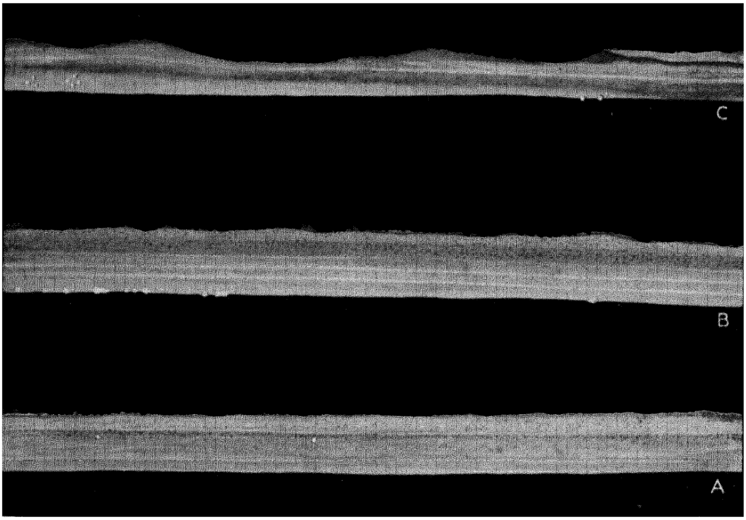
Andrews and Harter have recently published a paper on the morphology of reproduction in *C. fimbriata*. The most important portion of this paper is the method of production of the asci and ascospores in the perithecium. This is of little general interest to non-technical readers, and interested readers can probably consult the reference given. Some details on asexual reproduction are given which are reproduced below, and Fig. 28 is reproduced from their article.

The process whereby the conidia of *C. fimbriata* are abstracted within the sheath of the conidiophore has been discussed at some length by Halsted and Fairchild, and more recently Lehman has contributed some additional facts. The asexual spores of *C. fimbriata* are of two types, oval spores of olive-brown pigmentation and hyaline spores that are mostly linear in shape and extremely variable in size.

Lehman presented evidence to show that the walls of the endoconidia were generated anew by the protoplast and were not the result of longitudinal splitting of the conidiophore wall as claimed by Brierley for the endoconidia of *Thielavia basicola* (B. and Br.), Zopf.[1] Additional evidence of this fact is adduced here from the frequent presence of an intercalary element between newly formed endoconidia. The structure shown at (*a*) in Fig. 28 G may consist of lamellar substance that has adhered to the base of the newly abstricted spore. Lehman further contended that the thick-walled olive conidia were in no case formed endosporously, since the protoplast is distended from the ruptured tip before the conidium is abstricted (Fig. 28 C, *a*). In material with olive conidia formed in great abundance, a considerable number of spores can be found with two distinct walls, the inner wall appearing to be that of an endospore (B). In A, the outer wall of the spore is shown to be continuous with the sheath of the conidiophore, with the line of rupture just visible.

Germination of the thick-walled olive conidia (D) figure by Harter and Weimer, appears to occur rarely. Hyaline conidia (Fig. 28, E to L) are capable of germinating as soon as they are discharged from the sporophore, and water mounts from any area of a colony on agar media will usually show large numbers of germinated and germinating spores which disintegrate after having formed a chain of smaller endoconidia. There is normally no evacuation of spore contents as appears in Fig. 28, K, L. The one or more germ tubes form at a characteristic angle to the conidium (H to L), and may proceed at once to the formation of new endoconidia (H).

[1] *Threlaviopisis basicola* (Berk.), Ferr, according to information received from Mr S. F. Ashby, is the correct name for the endoconidial fungus.

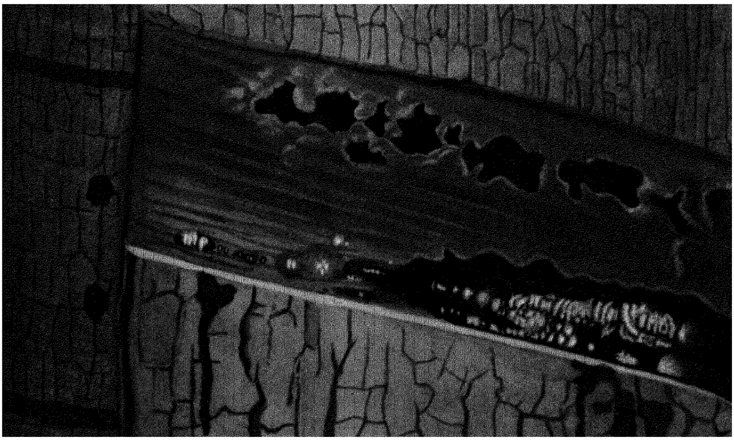


Brown Bast Cortex

A, Note slight brownish discoloration of the cortical tissues situated internally, not far distant from the cambium.

B, Note brownish discoloration becoming more generally dispersed through the cortical tissues and generally more prominent.

C, Typical appearance of cortical tissue showing advanced stage of Brown Bast attack.



Mouldy Rot

Tapping panel of rubber tree attacked by Mouldy Rot.

Note white surface mould and upper line of old wounds running parallel to tapping out.

In Petri-dish cultures and on sweet-potato roots in moist chambers, the aerial chains of conidia collapse and become suspended in droplets of water which condense among the aerial hyphae. Under these conditions large numbers of the hyaline spores germinate and the germ tubes grow downward to the surface of the medium. Conidia discharged beneath the surface of the agar germinate and grow upward, discharging new endoconidia above the surface of the medium. Germinating conidiospores very frequently fuse with one another and with neighbouring hyphae, forming an irregular entanglement of aerial mycelium having considerable rigidity.

Brown Bast

Cause = Physiological

This tapping panel disease caused great alarm about 1917–23, but now the particular nature of the affection and the important factors which influence its appearance and spread are much better known, there does not appear any valid reason for serious apprehension. The investigations of the writer (together with Lambourne) led to the conclusion that the disease was entirely physiological in origin and not bacterial as was held strongly by Keuchenius. This conclusion has not been controverted, and our physiological explanation for the appearance of brown-bast symptoms has received strong support from the physiological work recently published (1933) by Frey-Wisselinghe.

The disease has been known to exist in Java since about 1912, though it was confused with other panel diseases. "Burred" trees were common in 1912, when the writer first went to Malaya, and as "burrs" usually appear as a result of neglected attacks of brown bast, the disease was probably present in Malaya before that date. But it is obvious from the following statements that, in Malaya, both Gallagher in 1909, and Bateson in 1913, had noticed the symptoms which later became known as typical for brown bast, and the former made a shrewd guess as to the physiological origin of brown bast symptoms. Gallagher says:

The growths commonly called "warts" or "peas" are to be found on nearly all trees. Tapping does not appear to induce them as they are found on untapped trees of three years and older; I believe they are dormant buds. They should be taken out when quite young; this is easily done by a tap from a hammer or with a strong knife. The wound soon heals over completely. The practice of many planters having their old trees examined systematically at periodical intervals for these excrescences is worthy of wider application. The rough outgrowths, often several square inches or even square feet in area, which usually begin at the bottom on trees where the early tapping has been bad, seems to be a disease not due to any

parasitic organism but to *some derangement in the internal economy of the tree induced perhaps by severe tapping.*

Bateson says:

> Up to the present (1913) bark canker has not been recorded from the F.M.S., and the absence of this troublesome disease is a point on which planters may well congratulate themselves. There is another disease affecting occasional trees on some estates which is sometimes mistaken for canker, but beyond the fact that the bark is slightly discoloured and either ceases to give latex or yields a diminished amount, the characteristic symptoms of canker are lacking.

The slight discoloration, with diminishing or complete lack of yields, are characteristic symptoms of the early stages of brown bast attack. It has been recorded from Borneo and Ceylon and is probably present in all rubber-growing countries of the Middle East.

Symptoms.—The only certain macroscopic symptoms are the cessation or falling-off in latex yield, with the affected cortical tissues becoming somewhat succulent, i.e. waterlogged, and taking on a definite discoloration, ranging from blackish-grey or greyish-brown to a sepia colour (Plate III c). The earliest and most usual indication of brown bast is a slight discoloration of the bark in the tapping cut, which appears in small brownish patches or spots. Most writers emphasise the drying-out of a portion of the cut as a sure sign of approaching brown bast, but in many cases there is a preliminary substantial increase in latex-flow. Ultimately, however, the latex-flow ceases as the disease progresses, and the tree is said to go "dry". If a tree has been a normal yielder in full foliage and not otherwise diseased, a sudden increase or decrease in latex-flow is practically a sure indication that a brown bast attack is imminent. During the wintering months in Malaya, the drying-out of the cut alone cannot be accepted as a symptom, as during this period a number of trees become partly or altogether dry. Various investigators believe that the earliest macroscopic symptoms are antedated by microscopic changes in the affected tissues, and that trees liable to an early attack of brown bast can be detected by a microscopic examination. The writer is not prepared to subscribe to this view but supports Keuchenius, who states that brown bast cannot be diagnosed with certainty unless the macroscopic symptoms are well marked. The point is not one of major significance, for, with sufficient experience, brown bast can be detected, in most cases, quickly enough to allow of recovery, if the trees are rested from tapping for a period of three weeks.

Cases of brown bast on untapped trees have been reported from

Java and Malaya, but these are merely of academic interest. The initiation of the affection on the tapping cut is the only type of brown bast which needs serious consideration.

It has been definitely proved by numerous tapping experiments that overtapping, which results in the extraction of more latex from the tree than can be permitted if normal physiological relationships are to remain in a balanced state, is the primary cause of the disease. The term overtapping should not be misunderstood. The trees in a mixed stand vary considerably in their capacity for yielding latex, and a system of tapping which may result in brown bast developing in one tree may not be anywhere near the limit of safety for its neighbours. It is obvious, therefore, that for individual trees the term overtapping must be allowed considerable elasticity, i.e. a system of tapping such as the $\frac{1}{2}$ spiral cut daily, may result in brown bast appearing in some trees, but would not have this effect in others. Further, with regard to the excessive withdrawal of latex, it is very probable that the liquid portion, rather than the solid constituents of the latex, is of primary importance. This hypothesis, first stated by the writer in 1924, has been strongly supported by recent physiological work. While it is difficult to obtain absolute proof, the evidence for it is so strong that practically all investigators who have worked on the problem are in agreement, and believe the cause to be a physiological one. Keuchenius is the only investigator who may still hold the theory of bacterial origin, but he has not made any reply since 1924 to the writer's criticism of his work.

In our experimental work, a prominent feature was a sudden increase in number of brown-bast cases during certain months of the year. Thus, heavy tapping on an experimental plot showed no brown-bast cases from April to September; in this latter month 45 trees developed brown bast. Another quiescent period followed until December; in this month a further 57 cases were found. These quiescent periods between sudden rises in the number of cases are quite typical for heavy tapping systems, but it is unlikely they will show up prominently under normal systems.

The fact that over-extraction of latex was closely related to the incidence of brown bast was shown where a heavily tapped test plot remained free from brown bast over an eleven-months tapping period, when a sudden increase in number of brown-bast cases was definitely correlated with a sudden increase in yield.

During these experiments it was noted that the extension of brown bast down the tree was often stopped at the places where old "opening-up" marks were evident. It was further noted that, if

"spotted" in the earliest stages, brown bast in a large percentage of cases does not extend much below the tapping cut, but in about 14 per cent of cases the affection spreads to the base of the trees after heavy tapping, in spite of resting. These two points are of some practical importance with regard to the method of treatment recommended by Keuchenius and also offer a probable explanation of a problem which has been remarked npon by many authorities. In the early days of the rubber industry, when large numbers of superimposed cuts were put up the trees to a height of 10–15 ft., brown bast was apparently unknown. Harmsen has collected evidence (*vide* Rands) showing that with two superimposed cuts, brown bast makes its appearance first on the top cut in 80 per cent of cases. It is probable that in these early days the top cuts became affected with brown bast, but each tapping area below acted as an isolation barrier preventing the appearance of the affection in the lower panels. Little care, moreover, was taken in the matter of bark excision, and it is possible that affected bark was removed almost as rapidly as it appeared, in many cases. At the present time, however, it is fairly obvious from the burred condition of the tapping panels of old trees that they have commonly suffered from brown bast.

There is no definite connection between rainfall and brown-bast development, beyond the fact that sufficient rain must fall if good yields are to be maintained. Heavy brown-bast infections coincide with dry periods, if yield continues high over the dry period.

If extraction of latex is a feature of primary importance in initiating brown-bast symptoms, then *a priori*, good-yielding trees will be more readily attacked than poor-yielding trees. Experience and experiment both strongly support the statement. But it is wrong to assume that poor-yielding trees are more immune. It is a purely general statement with no real relation to susceptibility and immunity, for we have definitely shown that lower-yielding trees often develop brown bast earlier than higher-yielding ones. One fact was prominent, i.e. that if a high-yielding tree maintained its yielding capacity without big fluctuations, such trees did not suffer from an early attack of brown bast.

In the present stage of our knowledge it does not seem necessary to go into details of microscopic changes in the tissues or the symptoms in advanced cases, for on estates showing an abnormal number of brown-bast cases, the only economic method of control is to change the tapping system so as to reduce the output. However, if the disease is not detected early, the discoloration in the portion of bark which is drying-out may appear as a definite pale-brown line on the tapping

cut near the cambium (Plate III A). Between the brown line and the cambium the cortex may still be laticiferous and, if pricked down to the wood, will still yield latex. The more seriously affected areas are sharply defined by the difference in colour of the cortical tissue as compared with normal cortex. In advanced cases, the outer bark is frequently characterised by long or short longitudinal splits or cracks, a preliminary to scaling. This is more common when the disease commences about two feet above ground-level, and spreads downwards to the collar. Such cracks are most frequent from a point just above the collar (below an old cut), spreading along a lateral root.

The most distinctive microscopic feature, according to Sanderson and Sutcliffe, is the presence of meristematic tissues in brown-bast cortex, almost invariably in the vicinity of latex vessels, the latex in the enclosed vessels in the meristem tissues usually being coagulated. The remaining characteristics of brown-bast cortex, e.g. the deposition of tannins, calcium oxalate, excessive quantity of sclereides at an unusual depth, often very deep-seated, depletion of starch, etc., are considered to be secondary symptoms arising directly as a result of meristem activity. The disease is diagnosed by its secondary symptoms, which give the characteristic appearance of brown-bast cortex.

Treatment.—Two lines of treatment have to be considered: (*a*) Preventive; (*b*) Curative.

It is now generally accepted that the over-extraction of latex is the fundamental cause of the affection as it appears on the tapping cut. Exceptional cases of brown bast in untapped trees have been reported and there are authentic cases of brown bast appearing in places where wounding has taken place.

PREVENTIVE TREATMENT.—The obvious line of treatment is a change of tapping system which will decrease the output of latex, or in the case of individual trees, cessation from tapping. At the present time, it may be stated that cessation of tapping is the only treatment being carried out, and if the affection is detected in the early stages, three to four weeks' rest from tapping will result in the disappearance of the typical symptoms, when tapping can be resumed.

If a large number of brown-bast cases are continuously being found and it is considered undesirable to change the tapping system, inspecting coolies should be specially trained to note the symptoms and report suspected cases. An intelligent coolie can become very adept and, after some time, complete reliance may be placed upon him if a good choice has been made. If the disease is noted when the first few discoloured spots appear on the tapping cut and tapping is

stopped immediately, there is seldom any extensive spread into untapped bark below.

CURATIVE TREATMENT.—Prominence has been given in past years to several methods of curative treatment, but as stated, these methods are not much in evidence at the present date. It may be of interest to briefly note these various methods. They are as follows:

(1) Planing method.
(2) Peeling or stripping method.
(3) Harmsen's tarring method.
(4) The method of Keuchenius.

The *Planing Method* has been in common use in Java and is carried out in the following manner. First of all the borders of the diseased patch are determined, after which the bark and diseased cortex is planed off or scraped away with a tool consisting of a bent and sharpened piece of hoop iron with a wooden grip at either end. All discoloured tissue must be removed until healthy bark tissue is reached. It is said that in mild cases this method has been used with satisfactory results. The planed surface is covered with paraffin wax or grafting wax after it has dried.

The obvious danger in this method is that in many deep-seated cases of brown bast, the affected tissue lies so close to the cambium that it is practically impossible to scrape away all the diseased tissue without seriously wounding this important meristematic layer. If any diseased tissue remains behind after scraping, brown bast will reappear at a later date.

The Peeling or Stripping Method.—This method was first practised by Pratt, while later, Sanderson and Sutcliffe strongly supported it in Malaya. The borders of the diseased patch are determined in the usual manner, then a deep cut to the wood is made in healthy tissue all round the diseased patch. The edges of the area to be isolated are then gradually lifted and gentle leverage will bring away the whole of the diseased area. It is stated that the operation is made easier by first scraping away the outer bark layers. The exposed surface needs a cover to prevent it drying out by the sun. In Malaya the surface is shaded for twenty-four to forty-eight hours and then melted wax is sprayed over the surface with an ordinary garden hose.

This method is expensive, but it has the great advantage in that all the diseased tissue is undoubtedly removed. On estates where this method has been applied, excellent bark renewals over the stripped surface have been obtained. The peeling method requires a fair amount of skill, and unless great care is taken, severe damage may

be done. It is seldom, if ever, put into operation at the present date.

The Tarring Method.—Usually known as Harmsen's treatment, as it was first introduced by this investigator in Java. It has been used fairly commonly in Java but was not taken up to any extent in Malaya. In this method the area of diseased cortex is delimited as before; it is then isolated by deep vertical and horizontal cuts, but these should not be so deep as to penetrate to the wood. The bark is then scraped off to half its thickness and hot tar is painted on. The tar has to be heated until it starts bubbling. The writer cannot recommend the tar method, as many objections could be made against it. As it is now more or less inoperative, no good purpose will be served by pointing out the drawbacks and dangers.

The Method of Keuchenius.—The basis of this method is the isolation of the diseased tissue by means of deep cuts to the wood. The affected tissues are delimited in the usual manner, then a surface cut is made in healthy tissue surrounding the diseased patch, by a tapping knife. Following this, a deep isolation cut to the wood is made with a thin-bladed knife, along the channel cut by the tapping knife. When only small areas of bark are affected no further treatment is necessary, but if bark areas larger than 2–3 ins. are opened up, the outer cortical layers are scraped off. The latest recommendations issued in 1931 by the A.V.R.O.S. experimental station, Sumatra, are as follows:

In the case of small infections the practice of scraping the bark can be discontinued and instead of discontinuing tapping of treated trees, it is recommended for the future that such trees be kept in tapping but with a shortened cut.

Summarising, the treatment is now as follows:

Trees running dry and with discoloration on parts of the tapping cut are either reported by the tappers and tapping mandors, or treated by a special disease gang.

In the latter case it is desirable that all cuts be inspected twice per month, or, once per month when being tapped on alternate days. Immediately after cutting, the latex is scraped from the tapping cut toward the spout with a stick of hard wood.

The infections, if any are found, are treated in the afternoon.

Infections with a diameter of less than 10 cm. are considered small. (The diameter of a latex cup is about 10 cm.)

The boundary of the infection is accurately ascertained by means of a bent knife or a tapping knife.

An isolation groove is made right to the wood at a distance of a few centimetres outside the edge of the infection around the diseased part. This is done by cutting a groove to a depth of about half the bark thickness with a tapping knife, and in the middle of this groove a cut is made

down to the wood with a sharp knife, which can be made from an old tapping knife.

The bark is not scraped off, and tapping of such trees is continued over the diseased part.

If the diameter of the infection exceeds 10 cm. (i.e. when the infection cannot be covered by a cup), the infection is considered as a large case, and is treated as follows:

The edge of the infection is ascertained and an isolation groove made, as indicated above for small infections. Subsequently the outer bark layer is scraped off with a bent knife.

The scraped part is not tapped.

The tapping cut is shortened. If tapping had been carried out over $\frac{1}{2}$ of the circumference, the cut is shortened to $\frac{1}{3}$, if a $\frac{1}{3}$ cut had been used, it is shortened to $\frac{1}{4}$ of the circumference.

Tapping of the tree is not discontinued, but continued with the shortened cut, if necessary under the isolation cut or on the next tapping panel. Subsequently the tree is always tapped with the shortened cut, also on later panels, for the shortened cut prolongs the cycle for bark renewal so much, that discontinuation of tapping is no longer necessary.

As a measure of saving on costs for brown-bast treatment, it is recommended, in times of low rubber prices, that infected trees, which normally yield less than 20 c.c. of latex per tapping, should not be treated, but should be taken out of tapping.

It is also recommended that the treated trees be inspected every three months as to the formation of wood burrs, and to remove burrs which may have formed.

Recently, owing to the fact that in numerous cases brown bast has been found passing across the isolation cuts, the recommendation to isolate diseased tissue by deep tapping cuts has been withdrawn. The writer called attention to this feature in 1924 when 14 to 20 per cent of brown-bast cases passed across the isolation cuts, if tapping was continued.

Brown bast does not call for much attention in Malaya at the present time, but as its origin in any tree is purely a question of excessive yields, it may prove in the future to be of great significance in high-yielding areas developed by bud-grafting or seed selection. The writer does not think, however, that much reliance can be placed on preventive measures. Cessation of tapping, or reduction in length of tapping cut, will prove of major importance as they are at the present date.

In dealing above with the subject of brown bast the author has purposely jettisoned the numberless inspired journalistic efforts printed in local publications. Two articles need further mention. In addition to Keuchenius, an organic cause was mentioned by Belgrave in the very early stages of the investigations, and he wrote at the

time, "Inoculation experiments have not yet been carried out, but the mode of occurrence leaves little doubt that the fungus is the cause of the disease". The organism was first considered to be a *Spongospora* species. In a footnote he states that this identification was probably wrong and that the organism seen might come to be identified as one of the lower forms of Algae. He quickly rejected this opinion and was one of the first observers to suggest a physiological cause of the disease.

In 1921 Horne described symptoms of "Phloem Necrosis" in the bark of *H. brasiliensis* affected by brown bast. The breakdown of sieve-tubes in the case of a physiological disease of potato had attained prominence from Quanjers' work in 1913, and the present writer made careful observations on these lines early in 1920. This line of work, however, was relinquished early in 1921, because of extremely variable results which were obtained when brown-bast cortex in the earliest stages were examined. The results obtained in the first half of 1920 would have supported the explanation put forward by Horne, but, as was shown by later work, phloem necrosis could not be accepted as the immediate cause of brown bast. The morphological effects in the cortical tissues caused by the operation of tapping are but little understood even at the present date, and any suggestions based on the examination of pickled specimens should be supported by examinations of living material. Most investigators who have had the opportunity of working in the East are accepting the physiological explanation put forward in this section.

CHAPTER XII

MAJOR DISEASES (*contd.*)

Panel Diseases caused by *Phytophthora* and *Pythium* spp.—Black Stripe—Patch Canker.

PANEL DISEASES CAUSED BY PHYTOPHTHORA AND PYTHIUM SPP.

Reproduction.—In a previous section attention has been called to the reproduction of the fungi included in these groups by means of free-swimming spores. The orders *Phytophthoraceae* and *Pythiaceae* are closely related and species of each order are concerned in the causation of panel diseases of *H. brasiliensis.*

In species of *Phytophthora* and *Pythium* the vegetative portion of the fungus, i.e. the mycelium, is composed of hyphae which resemble a hollow tube, for the hyphae are not broken up into individual cells by the formation of cross walls. The fungus causing black stripe in Malaya lives almost exclusively in the diseased tissue, the hyphae growing in between the cells, i.e. *intercellularly*, but they also penetrate through the cell walls and continue development in the interior of the cell, i.e. *intracellular* development. After a time the reproductive phase ensues and a sparse aerial development may take place; on these aerial branches small, pear-shaped structures, i.e. asexual sporangia, are borne. In Malayan black stripe the aerial sporangia are not often seen in nature, even though this was the only reproductive element formed in pure cultures in the earlier investigations. Other *Phytophthora* species produce different forms of reproductive organs which are formed in or amongst the cells of the invaded tissues. These are known as (*a*) Chlamydospores, (*b*) Oospores. The former are asexual spores; the latter are sexual reproductive organs, and result from the union of a male and female element. Thus, we may have three different reproductive structures in a species of *Phytophthora*, two of which are asexual. In Malayan black stripe, oospores or chlamydospores were not found in the original investigations, neither in nature nor in pure culture. In Java, sporangia and chlamydospores are reported by Steinmann, while there is no definite record from Ceylon. The above remarks refer only to *pure* cultures and not to the *mixed* cultures which have been so intensively studied in recent years. A description of the three spore types of *Phytophthora palmivora*, Butl., is given below.

Sporangia or Zoosporangia.—The free-swimming spores which emerge from the sporangium are known as zoospores, hence the term *zoosporangium.* The asexual sporangia are thin-walled structures densely filled with finely granular protoplasm, with a less dense central vacuole. They vary from spherical to pear-shaped, with prominent and characteristic blunt-ended, thickened, hyaline papillae. They are very variable in size; Thompson gives the range for *P. palmivora* as $36 \times 75\mu$ in length and $21–36\mu$ broad. The normal development of the sporangium is for the protoplasm to break up into a number, 10–35 (most often 15–20), of smaller portions of protoplasm, which finally separate and are actively motile. These are the zoospores which escape through a hole in the wall formed by the disappearance of the papillae. The zoospores vary in outline from circular to pear-shaped and in size from 7 to 11μ. They are usually flattened on one side, and provided with two cilia of unequal length. They swim about freely at first but later on they become quiescent, rounded-off and finally germinate as an ordinary conidium. But often there is no development of the zoospore stage and the sporangium puts out a germ-tube and germinates in the manner of an ordinary conidium.

Chlamydospores, or Resting Spores.—These spores are round, $23 \times 50\mu$ in diameter. At first the walls are thin but later thicken up and may become as much as $3 \times 4\mu$ thick. In water, the chlamydospores germinate within twenty-four hours and form a greatly ramified mycelium, there being no production of zoospores. Steinmann reports that while the presence of light is favourable to the formation of sporangia, the generation of chlamydospores is favoured by darkness. Chlamydospores are considered to be modified sporangia and rarely develop on the surface; they are usually found buried in the substratum.

Oospores.—These are sexual reproductive bodies resulting from fertilisation. The oospores of *Phytophthora palmivora*, Butl., have not yet been described from pure culture but only from mixed cultures. Mixed cultures are those in which two different strains of *Phytophthora* obtained from different host plants are put into a culture tube and allowed to grow together. At the "spots" where the hyphae of the two strains meet, oospores are often developed. The female organs, i.e. Oogonia, are $28 \times 34\mu$ in diameter, and have a thick brown-yellow wall; the male organs, i.e. Antheridia, have a thin wall and are colourless, $10 \times 16\mu$ long and $13 \times 17\mu$ broad; they are attached to the base of the oogonium. The oospore resulting from the fecundated oogonium measures $21 \times 28\mu$, is round and colourless and has a thick wall $1 \times 2\mu$ thick. The oospores are formed inside the substratum. Germination is by means of a germ tube as in an ordinary conidium.

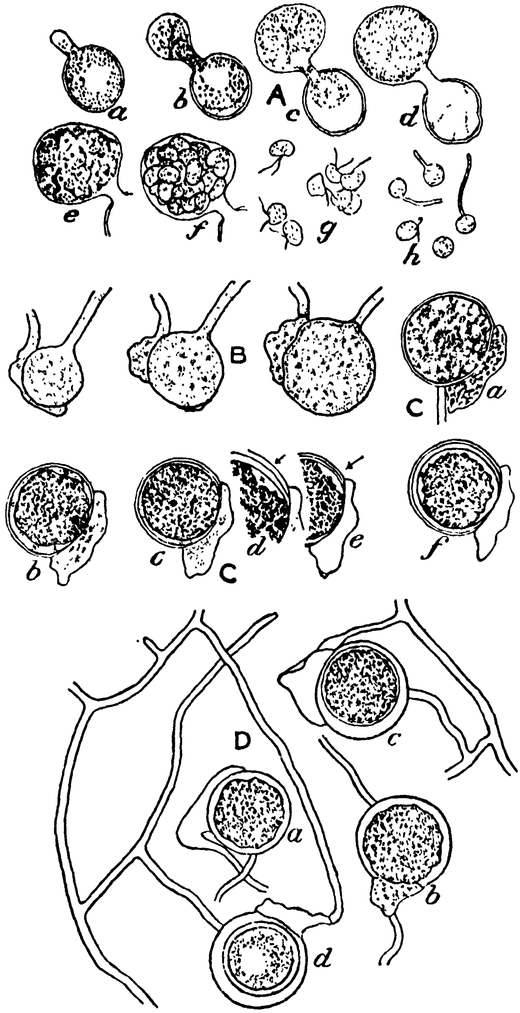


FIG. 31.—Geranium stemrot.

A, *a–h*, Stages in formation and germination of zoospores.
B, Three stages in early growth of sexual bodies.
C, Fertilisation: *a*, Beginning of oosphere contraction; *b*, passage of antheridial contents into subjacent oosphere through hole in fused walls; *c*, oosphere rounding up; *d*, *e*, and *f*, exospore wall formation by clear band extending around oosphere periphery. The clear band in *e* and *f* is drawn at twice actual width, to render it visible at scale of reproduction.
D, Oospores, showing attachment on slender stalk and relation to antheridium.

Fig. 31 illustrates the reproductive structures produced by the fungus *Pythium complectens*, Braun, and this illustration is repro-

duced from Braun's article. The production of zoospores, their germination and the various stages in the development of sexual reproductive organs, Oogonia and Antheridia, are detailed in the caption to the illustration.

The above is a very generalised account of the structural details of the type of fungus causing black stripe and patch canker diseases. The detailed morphological differences which would involve the consideration of statistical data regarding size of spores, mixed cultures, etc., is likely to prove too intricate for the majority of readers and the exact position is still by no means clear.

Black Stripe

Commonest cause in Malaya = *Phytophthora palmivora*. Butl.

This panel disease has figured under many common names such as black thread, black stripe, black line canker, bark rot, decay of the renewing bark, cambium rot and stripe canker. Petch remarks that the names black thread or black stripe are perhaps the most appropriate, and he utilises the designation black thread; the name black stripe is generally used in Malaya at the present time.

In Ceylon a disease resembling black stripe was first noticed in 1909, and in the following years it became prominent in Java and Sumatra. Black-stripe disease was reported in Malaya for the first time in 1916.

Symptoms.—Natural infection, which always takes place on the tapping cut, produces symptoms which are by no means obvious; short, vertical linear, shallow depressions about $\frac{1}{2}$ inch above the cut being the only external signs of attack for a considerable time (Fig. 32). If the bark is pared off, dark lines are found beneath the depression together with other lines which do not appear on the surface.

In Malaya, the black lines extend into the wood, widening as they go into stripes or bands, and it was quite common to find stripes $\frac{1}{4}$ inch broad and $\frac{1}{2}$–$\frac{1}{4}$ inch deep in the wood at very early stages of infection (Fig. 33). This very early and rapid, radial and deep penetration into the wood was most noteworthy during the investigations in 1916 in Malaya, and up to that time other investigators had not emphasised this particular feature. Petch states: "The effect of Black Thread extends into the wood and black lines may be found there running up and down the stem for some distance. . . . It has not yet been demonstrated that the causal fungus is present in these streaks."

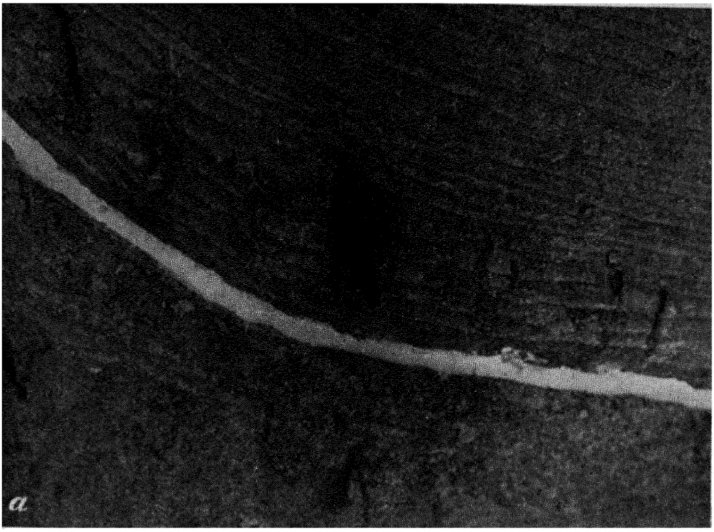


FIG. 32.—Typical appearance of a black stripe affection on a tree growing under dense shade.

Note.—Vertical, depressed stripes, and darker area about midway along the cut, which represents a rotted bark area where several stripes have coalesced.

FIG. 33.—Cortical tissues stripped away to expose wood surface and black stripes therein. (From Bull. No. 31, Dept. of Ag. S.S. & F.M.S.)

On this basis he argues that there is no necessity to cut out these lines or to cut out any wood. While this statement has been supported by experience in Malaya, the writer reported in 1917 that, as far as black stripe was concerned, the fungus had been isolated from diseased wood taken at a depth of $\frac{3}{4}$ inch in the stem. There is no doubt that in Malaya the fungus is active at a considerable depth in the discoloured wood tissues. Dastur states that it seldom runs below the tapping cut in Burma, but Petch and Rutgers record instances where the decay travelled downwards to involve the untapped bark. These cases, however, appeared to be exceptional, whereas in the Malayan outbreak in 1916, the decay in the wood was often found one or two inches below the tapping cut, while rare cases of extensions exceeding six inches have been met with. Considerable variation exists. In many cases the disease is more superficial and wood penetration is slight or absent; in others there is rapid coalescence of stripes and rotting of the tissues, although tapping may have been stopped at the earliest signs of the disease. These variations may be due to the fact that several strains of *Phytophthorae* have been found causing black stripe, and these closely related but different strains may show varying degrees of virulence.

The fungus is seldom visible externally except on wet mornings, when a delicate white "bloom" may be seen just above the diseased tapping cut. This bloom consists of the mycelium of a species of *Phytophthora*, and a very limited number of sporangia of that fungus mixed with the mycelium and spores of a *Fusarium* sp. Bacteria are also present in abundance.

In all cases in which a causative agent of black stripe has been determined, the fungus has proved to be a species of *Phytophthora*. Thompson, in his comprehensive work in Malaya, isolated three different species of *Phytophthora* from naturally occurring cases of black stripe. The three species are:

P. palmivora, Butl.
P. meadii, McRae
P. heveae, Thompson

In the earlier work on black-stripe disease, the name of the causal fungus has been generally accepted as *Phytophthora faberi*, Maubl. This is now considered to be the same species as *Phytophthora palmivora*, Butl., and on the ground of priority this name must be used. This is the commonest causative agent of black-stripe disease in Malaya.

The disease has now been recorded from all rubber-growing

countries in the Middle East, i.e. Burma, Ceylon, Java, Malaya, South India and Sumatra.

Factors affecting the Intensity and Spread of Black Stripe.—As stated above, only thin-walled sporangia were found in the early investigations from 1916 to 1920; chlamydospores and oospores were not found, either in culture or in nature. This raised a difficult problem for which no explanation could be found at the time. In the absence of resting-spores, i.e. chlamydospores and oospores, it was difficult to see how the fungus causing Malayan black stripe could tide over unfavourable seasons. But now that we are aware that several different strains of *Phytophthora* are concerned in black stripe, the problem is not so difficult. Further, Thompson has shown that two strains of *Phytophthora* isolated from tissues suffering from black-stripe disease produce numerous chlamydospores in culture. These thick-walled spores are capable of resisting drought conditions for some considerable time, and so unfavourable periods for development and growth of the fungus may be lived through safely.

But various factors arise for consideration. Survival through unfavourable periods may be facilitated through the presence of one or more native host plants not yet recorded; or there may be a slight unnoticed amount of leaf-fall with corresponding "die-back" of the branches allowing the fungus to "winter" in the latter. Recently we have gained new light on such factors. Reydon has recorded outbreaks of black stripe on mature rubber, the species of *Phytophthora* causing which had spread from small seedling plants of rubber growing under a thick cover of *Centrosema*; and in another case the leaves and stems of the seedling rubber plants were found to be diseased with a species of *Phytophthora* prominent on and within the diseased areas. It is pointed out, when describing patch canker, that *Pythium complectens*, Braun, has been isolated from diseased rubber seedlings, and as this fungus is closely related to species of *Phytophthora* and is evidently a common soil-inhabiting fungus in rubber plantations in Malaya, it is not stretching the point too far when it is suggested that the situation reported from Java might arise in the near future in Malaya. This possibility may influence the question of establishing "forestry conditions" in rubber areas, for rubber seedlings are recommended for extensive use in this connection.

But, given the fungus, the main factor in epidemic spread and intensity of infection is moisture. Without high humidity, external mycelium does not grow and sporangia do not germinate, while zoospore formation takes place only in the presence of water.

Epidemics of black-stripe disease have attained their greatest

intensity in Burma and South India during the S.W. monsoon, when daily rain falls persistently from June to September, with the result that atmospheric humidity is constantly high. The opinion was expressed that the evenly distributed rainfall in Malaya might be as favourable to the growth of the fungi causing bark diseases as the alternating wet and dry periods in other countries which are definitely affected by the S.W. monsoon. This has proved not to be the case, and intensive epidemics in Malaya are strictly localised to districts where the lie of the land results in a persistent high humidity during the period of greatest rainfall, viz. from October to December. Rubber plantations situated in valleys between high hills are most subject, and the sudden spread of the disease after the first cases appear is often very alarming. But on the great majority of Malayan estates which have suffered owing to outbreaks of black stripe, a 10 per cent infection would be considered a high figure. From the pathological standpoint, especially in Malaya, it should not be forgotten that records showing total daily rainfall may be misleading, for the greater part of the rain (estimated at two-thirds) falls during afternoon thunderstorms, while the mornings are usually hot and dry and unfavourable to fungus growth. There seems no reason to doubt that the comparative freedom from black stripe enjoyed by Malayan rubber plantations may be cogently argued from this feature, for even during the heaviest rainy periods, daily bursts of sunshine may be expected.

After rainfall, atmospheric humidity profoundly influences the development of the fungi associated with black-stripe disease. Here again, average returns of atmospheric humidity are useless. It has been shown that the fungus will not grow on agar smears when the relative humidity falls below 90 per cent, so it appears that an ordinary Malayan day would check the spread of the disease, for on rainless days the relative humidity falls from *circa* 90–98 per cent at night to 82–86 per cent at 10 A.M., and to 60–75 per cent for the rest of the day. Of course, the onset of rain will raise the atmospheric humidity, but it is not necessary that heavy rain should fall to bring about a high relative humidity. Little or no rain may fall, but heavy overcast weather may bring about a succession of mornings with high relative humidity, and it is during such periods that the spread of black stripe reaches its peak. Such periods are to be feared more than those when rain falls several mornings in succession; if rain supervenes early in the morning, tapping is stopped and then there is less chance of infection.

Tests made by Pratt and others appear to indicate that tapping cuts near the ground are more liable to infection than cuts a consider-

able distance away. The evidence seems hardly conclusive and the writer agrees with Petch on this point. The enormous fall in percentage number of cases between cuts at five inches high with a 30 per cent infection, and those at eighteen inches high with a 3 per cent infection can hardly be accounted for by atmospheric differences, and it seems probable that some factor other than the height of the cut was operative. Harmsen furnishes figures which support those of Pratt, but in any case the matter seems one for further investigation.

Other factors which might be expected to influence the incidence of black stripe are depth of tapping, mode of tapping, daily or alternate daily, etc., and slope of cut. The effect of tapping systems in general has been discussed in a previous section. Harmsen has maintained that the percentage infection was much higher for deep cuts than for shallow cuts, but results obtained from tests carried out in Malaya do not support this view. Results on lightly tapped and deeply tapped bark show no appreciable difference in percentage infection while attacks could be discovered earlier on the deeply tapped trees—an important consideration in control methods.

Treatment of Black Stripe.—The attacks of black stripe in Malaya in 1916 were noteworthy for virulence; coalescence was rapid and the area of bark rotted was large, while wood penetration was much deeper than that described in other countries. During the last few years, however, few reports of outbreaks of this disease have been sent in, and there does not appear to be any good reason for anticipating epidemic outbreaks except under abnormal weather conditions.

In 1916, and for a few years afterwards, various treatments were tried. Pratt first showed that excellent results could be obtained by using weak solutions of proprietary disinfectants with fungicidal properties. It should be understood, of course, that the prosperity prevailing in Malaya and other rubber-growing countries prior to 1920 would largely influence the recommendations for disease treatment. For instance, scrap rubber from the tapping cut is an article of value if the price of rubber is high, and in the years 1916–17 the possible deterioration of the scrap rubber through the application of fungicidal fluids had to be considered. This problem is of no importance at the present time, for little trouble is taken even to collect scrap rubber from the tapping cuts.

It does not now seem necessary to consider all the various treatments which have been recommended. The fungicidal fluids most commonly used in Malaya have been Agrisol in 20 per cent solution, Brunolinum Plantarium in 20 per cent solution, Izal in 3 per cent

solution. Any of the fungicidal fluids listed in another section could probably be usefully employed. If the infected trees are taken out of the tapping round, the diseased areas are painted over with the solutions of strength given above, followed by a second painting four to five days later. This is usually sufficient except in neglected and refractory cases, when a longer rest and further applications of the fungicidal solution may be necessary. If tapping is continued, more frequent applications may be necessary, and painting after every tapping may have to be undertaken.

The disinfection of tapping knives has been recommended, but it has been shown that preventive painting alone will control the disease, so that disinfecting the tapping knives, while theoretically an advantage, would merely be over-elaboration.

Murray reports a disease of young bud-shoots caused by *Phytophthora palmivora*, Butl., and the following quotation is given for the sake of completeness, though the disease has not yet been reported from Malaya:

Economic Importance.—The disease has not, up to the present, proved a serious factor in retarding the development of young buddings in Ceylon, and has only been reported from three estates. As is indicated above, the progress of the disease is largely dependent on wet weather conditions, as would be expected from the zoosporangial method of reproduction of the fungus. The chief danger would appear to lie in the outbreak of the disease in a bud-wood nursery in wet weather. If the bud-shoots were very young they might quickly be killed back to the stock and a supply of valuable material might thereby be lost. It is unlikely that older shoots with several growth increments would be completely killed, since inoculations have shown that the fungus does not readily attack or spread to the more mature portions of the shoots. There is the possibility, however, that *Diplodia* and other secondary fungi might gain entrance to the diseased shoot and cause a complete die-back.

Occurrence in other Countries.—The disease is known in East and West Java but is stated to occur only when the atmospheric conditions are wet. The fungus causing the disease is apparently the same strain as that isolated in Ceylon. In Sumatra a severe attack of *Phytophthora faberi* (*P. palmivora*) in bud-wood nurseries is reported by d'Angremond, but it is not known whether this disease was caused by the same strain. In Malaya, Weir describes a disease which attacks the young bud-shoot at its extremity and mentions a *Phytophthora* as a possible causal agent.

Patch Canker or Claret-coloured Bark Canker

Commonest cause in Malaya = *Pythium complectens*, Braun.

This disease was first discovered on *Hevea*, in Ceylon, about 1903. It has since been reported in Java, Sumatra and Fiji, but it has never

been found to be of common occurrence in Malaya. Recently it has been reported to be common in Kedah, and has been found to be associated with damage by lightning on numerous estates in other parts of Malaya.

Causal Fungus.—Steinmann reports that, according to the investigations of Rutgers and Vischer, this disease of the tapping panel is caused by the same species of *Phytophthora* which causes black-stripe canker. Petch states: "The *Phytophthora* which causes claret-coloured bark canker is identical with that which causes the similarly coloured canker in Cacao". Recent work in Malaya showed the constant association of a *Pythium* sp. with patch canker following on lightning damage, while Thompson isolated two species of *Phytophthora* and one species of *Pythium* from naturally occurring patch canker in Malaya. Steinmann points out that Hartley in an unpublished paper, had stated that the differences between the various *Phytophthorae* which cause patch canker in cacao and black stripe and patch canker in *Hevea* are comparatively small, and that they should not be considered separate species. This question of the identity of the fungi causing canker in cacao and *Hevea* is not as important in Malaya as in Ceylon and the Dutch East Indies. In the latter countries mixed plantings of cacao and rubber have been a fairly common feature in past years, and the intermixture of these two crops, both susceptible to attack by the same fungi, has probably resulted in more intense attacks of patch canker being experienced on *Hevea* than has been the case in Malaya.

Thompson records the fungi isolated from naturally occurring cases of patch canker in Malaya as under:

Phytophthora palmivora, Butl. (rubber group)
Phytophthora sp. (undetermined)
Pythium sp. (probably *P. complectens*, Braun)

In connection with the fungi listed above, the writer submitted two cultures for examination to Dr. S. F. Ashby, Mycologist, Imperial Mycological Institute, one of which (*a*) was a *Pythium* sp. associated with lightning damage on rubber trees, the other (*b*), being isolated from a diseased rubber seedling. His report was as follows:

Both of the isolations yielded a similar fine silky, radial growth on maize extract agar, the hyphal characters being also much alike.

Transfers to water from a young growth on bean agar of (*a*), after two days at 23° C. numerous, spherical sporangia, borne as a rule on lateral branches, were produced; zoospores were developed freely after the culture was brought into the cooler room. The contents of the sporangium passed

into a vesicle, in which, after about 10 minutes at 21° C., zoospores had differentiated and had begun to swim away.

The evacuation tube was short (¼ to ½ the diameter of the sporangium). Sexual organs were scanty on the mycelium growing into the water from the inoculum after a further 2–3 days. Conidia (sporangia) were formed abundantly on bean agar and sexual organs fairly freely. The antheridium was applied laterally to the oogonium, clasping it frequently over half its surface as in *Pythium complectens*, Braun. In sporangia and size of sexual organs, the strain agrees very closely with that described by A. Thompson from patch-canker of *Hevea* rubber (*Malayan Agric. Jour.* xiii. 139, 1925) and is doubtless the same species. Like the earlier isolation from patch-canker, it can be considered a strain of *P. complectens*, although not quite identical with Braun's strain.

The form (*b*) produced sporangia less freely and tardily in water; they were quite similar, however, in size, evacuation tube, and vesicle. Sexual organs were produced more freely in water; they were quite similar to those of the other strain. Sexual organs were formed freely on maize-meal agar but sporangia were very scanty on bean, maize, and quaker-oats agars. This strain differs from the other apparently only in the more pronounced degree of the sexual over the asexual reproduction, It was a pure culture, but the culture (*a*) carried a bacterium which seemed to have no inhibiting effect on vegetative growth and might have promoted asexual reproduction. Both strains produced an abundant aerial mycelium on the agars.

In 1928, Weir reported that he had made many soil isolations, and commonly obtained a *Pythium* sp. in culture. This species would almost certainly prove to be *P. complectens*, and the microphotographs illustrating the sexual organs of the fungus-causing patch-canker were taken by Mr. R. M. Richards, and are quite typical for *P. complectens* (Fig. 34 *a*, *b*). This fungus is obviously the most frequent species found closely associated with affections of the rubber tree, and may reasonably be considered the commonest cause of patch-canker in Malaya. Details of reproductive structures produced by this fungus are given in Fig. 31.

Before proceeding to the description of the symptoms of patch-canker it will be of interest to state shortly the characters of the cortex of a healthy tree as it appears when carefully scraped away. Healthy *Hevea* cortex, if not previously tapped, has a thin green layer underlying the outer, brown corky layer. Beneath this green layer, the cortex is yellowish, becoming whiter as the cambium is approached. In renewed bark, the green layer is never prominent and is usually absent, and the outer living layers of the cortex are, in part, a clear red. Frequently this red coloration runs in a narrow zone, just within the cortex. This clear red coloration is a normal appearance which may persist in the renewed bark for many years.

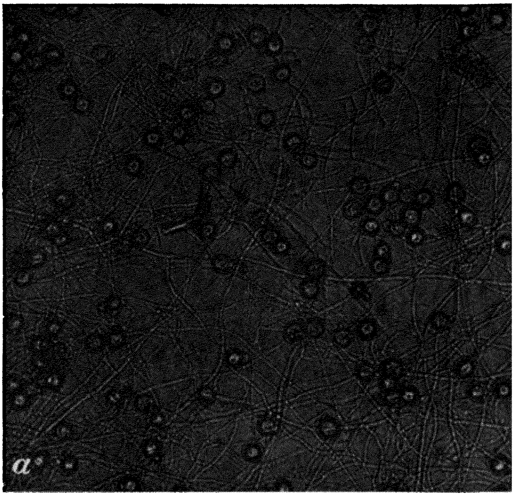


FIG. 34 *a*.—*Pythium complectens*. Sporangia and Oogonia of *P. complectens* developed in pure culture. (Photograph by Mr. R. M. Richards.)

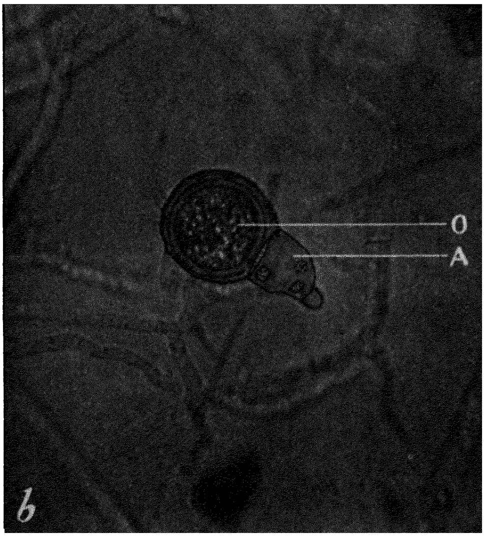


FIG. 34 *b*.—Enlarged photograph of above to show a single sexual reproductive body. (Photograph by Mr. R. M. Richards.)

Note.—A male organ—Antheridium, clear and devoid of protoplasm which has passed into O—female organ—Oogonium, with dense protoplasm.

Symptoms.—In the early stages of patch-canker there is little outward indication of the disease. If the tree has acquired a thick, outer brown bark it is only by scraping away the outer tissues that the diseased areas become visible. From the diseased areas a reddish or purplish liquid may exude in many cases and this dries on the surface in small streaks. In very wet weather, this may occur when only a small patch of bark is diseased, but more usually it only happens after a fairly large area has become affected. But when the disease has reached an advanced stage, the decaying bark attracts boring beetles; frequently it is not until this stage is reached that any trouble is noted. In some instances an attacked tree ceases to yield latex; but

FIG. 35 *a*.—Tree affected by patch canker following on lightning strike. Corky bark lightly scraped away to expose external surface of diseased cortical tissue. Note dark discoloration of cortical tissue.

this is not a certain symptom of the disease, as it is in the case of brown bast.

If the outer bark layers of a tree suffering from patch-canker are scraped lightly so as to expose the diseased tissue, a thin black layer is first met with, and the cortex beneath this is moist and discoloured (Fig. 35 *a*). When recently attacked it is greyish or yellowish-grey with a well-defined black border, but in advanced cases it becomes claret-coloured or purple-red. Frequently the diseased cortex is dirty red when cut, but soon darkens to purplish-red on exposure. It is hardly possible to confuse this usually muddy looking, discoloured tissue with the clear, translucent red zone characteristic of healthy cortex of renewed bark, and the discoloured areas are always clearly marked off by a black line from the surrounding healthy tissues.

The disease pursues its course by infecting the external cortical layers; it then works inwards towards the cambium, spreading out at the same time more or less equally in all directions. This indicates that all the cortical tissues are indiscriminately attacked in turn and that the fungus does not confine its activities primarily to any particular type of tissue system, such as the medullary rays. Thus, the black-stripe fungus utilises the medullary rays for rapid radial spread into the wood, and because of this we get the characteristic symptoms. In most cases, a patch-canker infection would be detected before it has fully penetrated through the cortex to the cambium, but if left alone it will kill the cortex right down to the cambium and spread

FIG. 35 *b*.—Patch canker. Affected bark seen in Fig. 35 *a* stripped away from wood to show inner surface of cortex which was in contact with the wood. (Figs. 35 *a* and *b* from *Annals of Applied Biology*, vol. xx. No. 1, p. 1.)

Note.—The cortical tissues are diseased throughout its thickness. White areas show where latex has exuded from diseased areas to coagulate in spaces between wood and cortex formed by shrinkage of diseased cortical tissue.

laterally as long as growth conditions are favourable to the fungus (Fig. 35 *b*). It may thus extend over large areas of bark, and ultimately kill the tree, without producing any open wound or giving any outward indication except the bleeding already mentioned. When dry weather sets in, however, the disease is generally checked, and the affected cortex then dries up and forms a scale which ultimately falls off. The most serious cases of patch-canker are those in which the tree is attacked at the collar (Fig. 36). The disease may then run rapidly round the base of the tree and kill it in a few weeks. In Malaya this type of collar infection is met with most commonly as an after-effect following lightning damage. It will be dealt with in detail in a later chapter, but it may be stated here that Rutgers and La Rue mention a cherry-coloured or purple discoloration of bark and cam-

bium in cases of lightning wounds. They state this discoloration remains visible for a short time and can only be seen in cases which are diagnosed at once.

If the primary infection takes place on the tapping cut so that the recently tapped, renewing bark is involved, the diseased tissue often remains yellowish-grey in colour, i.e. does not assume the characteristic claret colour. But where it extends into the untapped area under the tapping cut, as usually happens, the diseased tissue assumes the typical claret colour. There should not be any confusion between black stripe and patch-canker, for the typical colour of patch-canker is quite distinct and it spreads uniformly in all directions from the point of infection as a continuous sheet of diseased tissue with no tendency to form lines or stripes, which at a later stage may fuse

FIG. 36.—Showing wounds at base of tree caused by an attack of patch canker at the collar. (Photograph by Mr. A. Thompson.)

together. During the dry seasons experienced in Java and Ceylon the disease automatically ceased to spread, or only spread very slowly. Under a protracted dry-weather period, the affected bark patches dry out and are scaled off by the action of the undamaged cambium beneath.

Treatment.—As stated above, under ordinary circumstances, patch-canker is not a common disease in Malaya; this remark needs some reservation perhaps, for the situation seems worthy of further review in the Kedah and North Perak districts.

The recognised treatment for patch-canker is to strip off the diseased bark area in one piece; but if this is not possible, to take out the diseased tissue in convenient lumps, treatment which could only go astray through sheer carelessness. The first operation is to paint over and about the diseased area with a strong fungicidal solution, such as Izal, in 5 per cent solution, so as to kill any aerial mycelium

on the surface. A little time is allowed to elapse and then the diseased area is delimited by very light scraping. The clearly defined edges of the diseased bark are usually easily traced out; when this has been done a cut down to the wood is made, including about one inch of healthy cortical tissue within the area isolated by the cut, together with the whole of the diseased tissue. The knife is then carefully inserted beneath the edges of the isolated area, and is gradually worked right round to loosen the diseased patch at the edges. This operation demands care but, if not hurried, little difficulty is to be expected. When the edges are loosened, the knife is carefully inserted and gentle force applied to lever out the diseased patch. Undue haste will only result in disappointment. When removed, the diseased patch should be burnt as quickly as possible; it is useful to immerse the diseased patches immediately in solar oil, a receptacle containing which should be carried round by the coolies undertaking the work. The stripped surface is then protected by a wound-cover to prevent the entrance of boring beetles; tar is recommended in Ceylon, while in Malaya asphaltum-kerosene or asphaltum-solar oil mixture is generally used.

If a serious attack is experienced and large numbers of trees need treatment in the vicinity of the tapping cut, it may be best to adopt the scraping method, but the gravest precautions must be taken to prevent small pieces falling to the base of the tree and causing infection at the collar. Scraping can only be recommended with safety for treatment during periods of dry weather, when the diseased part may then be scraped away so as to remove most of the cankered bark, the scraping being continued until latex begins to issue from the inner cortical layers in minute drops. This is a sign that the limit of the diseased part is being reached as cankered bark does not yield latex. The remainder of the diseased cortex is then left to dry up and scale out. If the disease has penetrated to the wood, the whole of the cankered cortex has to be cut out. According to Malayan experience of the scraping treatment, when the operation has been carried out at some height above ground-level, an attack of patch-canker at the collar follows later. As stated above, this is the most dangerous form of the disease.

The following is a summary of the treatment required for patch-canker:

(1) Paint infected area with a solution of 5 per cent Izal to kill aerial mycelium or sporangia.
(2) Allow 30 minutes to elapse, then delimit diseased area by very light scraping.

(3) A cut down to the wood is then made with a sharp knife to include one inch of healthy cortical tissue with the diseased area.
(4) The bark area isolated by the cut is then carefully "stripped" off as indicated above.
(5) When the stripping has been carried out, the exposed wood surface must be protected by painting over with tar or covering with asphaltum-solar oil mixture.

CHAPTER XIII

MINOR PANEL AFFECTIONS

Marasmius palmivorus, Sharples—Internal Bark Fissures—Drying-out of the Tapping Panel—Squirrel Damage—*Acanthopsyche snelleni*.

MARASMIUS PALMIVORUS, SHARPLES

ABOUT the end of 1922 and the beginning of 1923, Thompson reported that the renewing bark of rubber trees had been recently damaged by a fungus similar to one which formerly was observed to grow superficially on young bark at the top corner of a tapping panel. The fungus, which was referred to the genus *Marasmius*, had not been observed to penetrate through the bark into living cortical cells before the 1922 outbreak, and it disappeared normally by natural scaling of the bark. But in 1922 slight penetration through the bark on the tapping panel was noted in a few instances. Recently (June 1933), numerous cases of this disease have been reported from one estate and there cannot be the least doubt that the fungus is actively parasitic, rotting the bark and cortical tissues of the newly tapped surface down to the wood.

Symptoms.—During the last year two outbreaks of *Marasmius* bark rot have been observed. These developed normally as described by Thompson, who says: "Trees which were opened up for tapping on January 1st showed the disease after three weeks daily tapping". Both cases in 1933 showed about two to three inches of bark removed by tapping, and both were newly opened-up panels for test tapping on trees, some seven years of age. On estate A, the trees were first tapped on April 1st, 1933, and on June 5th a visit of inspection was made. The tapping system was ½ spiral, alternate daily, opened up at a height of 22 inches. The affection was spread over about 200 acres of closely planted rubber, and by the middle of June, over 400 trees showed the external strands of the fungus growing over the tapping panel.

As stated by Thompson, the plates of mycelium are found in one or all the corners of the tapping panel, but they are most commonly found in the upper corners. The reason for this has been recently discovered.

In the last case examined in 1933, the affection occurred on an

area similarly closely planted and the infection was a heavy one. The fungus not only grew over the surface of the tapping panel but grew out and covered the vertical channel which leads the latex to the latex-cup. In both cases the virgin bark was noticeably more scaly than usual, and the external fungal strands appeared to be running from beneath the bark scales on the upper boundary of the tapping panel and then on to the tapping panel itself, growing downwards towards the tapping cut. If the right conclusion is drawn from this appearance, it is very probable that the fungus strands filling the vertical channel would be growing out horizontally across the channel and not passing upwards or downwards. This proved to be the case. The fungus strands were growing out from the pre-infected bark scales which had been cut through by the tapping knife when the channel was made.

Thus, the scaly bark found before tapping is a diseased condition, the scaliness being brought about by the development of circular cork-cambia around patches of diseased outer cortical tissue, which later dry up and scale off. This is plainly seen when the bark is examined microscopically. When tapping is started in virgin bark, the fungus does not make its appearance from underneath the scales on the upper boundary of the tapping panel until two to three inches of bark have been excised by the tapping operation. The fungus cannot appear from underneath the bark scales below the tapping cut as long as tapping is continued, but since the fungus strands grow downwards to cover the tapped bark more quickly than the tapping operation opens new areas of freshly tapped bark, the tapping panel may become wholly covered by the fine, silky, mycelial threads. The cases seen this year show that the fungus can actively penetrate through the thin, recently tapped, renewing bark, completely passing through the cortical tissues to the wood, and causing a definite rotting of the bark. The newly developing cortical tissues are rotted down to the wood in a band running parallel to the tapping cut about $\frac{1}{4}$–$\frac{1}{2}$ inch broad and several inches in length, the rest of the renewing bark being covered with surface mycelium only, for the tissues immediately underneath the outer bark layers appear quite fresh and green.

Thompson says that one of the first signs of attack is the appearance of a small fan of white mycelium $\frac{1}{2}$–$\frac{3}{4}$ inch above the tapping cut, later forming a small plate of white mycelium, with a mycelial fan at the edges. A number of these plates may be formed; they are commonly found in one or all the corners of the tapping panel. Later some of these plates may fuse together into several patches which may

be from 6 to 8 ins. diameter. In the latest outbreak (1933) the whole of the tapped surfaces were covered with fine, silky strands of mycelium, giving a silvery white, external appearance in advanced cases. The diseased bark areas are quite conspicuous, on account of their covering of whitish-grey mycelium, which is white at the edges (Fig. 38). The mycelial plates and strands resemble those produced by species of *Marasmius*, and when fructifications are found they will probably belong to this group. (This has since been found to be correct.) Figs. 37 and 39 show the habit of growth of the fructifica-

FIG. 37.—Fructifications of *M. palmivorus* (?) growing *in situ* (natural size), developed in laboratory.

tions. These will need further study as they show features very similar to those of *Marasmius palmivorus*, described by the writer from coconut and oil palms. The following is the description given for this fungus, which is regarded as a species new to science:

MARASMIUS PALMIVORUS, SP. NOV. *Under Dry Conditions.*—Pileus $\frac{1}{2}$–$\frac{3}{4}$ inch across; umbonate; smooth, slightly striated. Upper surface Eosine Pink when young, Shrimp Pink later (Ridgeway), glabrous. Margin incurved when young. Gills pure white; attached when young but in old specimens becoming slightly detached from stalk; no cross veins; thick, distant. Stalk $\frac{1}{2}$–$\frac{3}{4}$ inch high. White, glabrous, solid, slightly bulbous at base; the bulbous base often shows same colour as

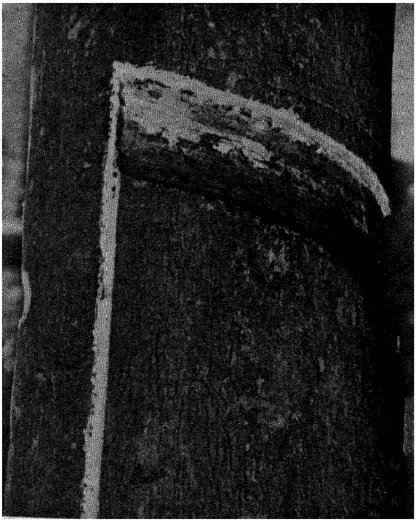


FIG. 38.—Mycelium of *M. palmivorus* (?) on panel of rubber tree and in vertical tapping channel. Mycelium on panel has not yet spread actually on to the tapping cut.

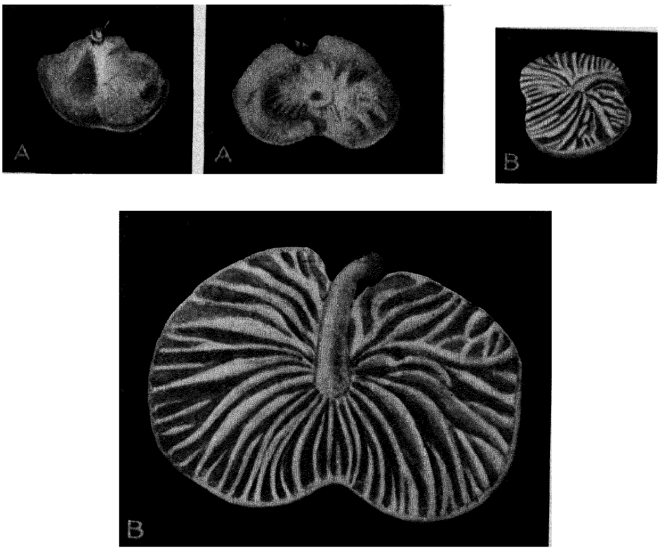


FIG. 39.—*Marasmius palmivorus*.

A = Upper Surface of Pileus. B = Under Surface showing gills.

Note.—Great variability in size of fructifications. The illustrations are natural size and the small ones represent the fructifications as seen in the field. The large type are developed in the laboratory in the presence of constant supplies of moisture.

upper surface of young pileus. Single or caespitose. Spores hyaline, $10 \times 5{\cdot}5\mu$. Slightly beaked when mature.

Under Moist Conditions.—Pileus white and transparent; when young shows traces only of brownish-red colour, 2–3 ins. across. Much convoluted with upturned edges. Stalk 1–2 ins. high. Bulbous base usually retains traces of pink colour.

Hab.—On tapping panels of rubber trees, and on leaf bases of coconut and oil palms.

Treatment.—There is no reason to suppose that this disease will not prove amenable to treatment if proper precautions are taken. No fruiting bodies have been found in nature up to date, and the only source from which fresh infections can originate is the sterile mycelium, portions of which may be carried from one tree to another on the tapping knife. If tapping is stopped for a fortnight, one painting with a strong fungicidal solution, or two paintings with a weaker solution, should be sufficient to kill out the fungus. A summary of treatment follows:

(1) Cease tapping for two weeks.

(2) Paint once with a 20 per cent solution of Agrisol, Brunolinum Plantarium or 5 per cent solution of Izal.

Or (3) as an alternative to (2), paint first with a 10–15 per cent solution of Agrisol or Brunolinum Plantarium, or a 3 per cent solution of Izal, to be followed by a second painting seven days later; tapping may be recommenced seven days later. Before reopening the tapping cuts, the scaly bark above the tapping panel and beneath the tapping cut should be scraped away, so as to remove the primary cause of infection.

Internal Bark Fissures

Sutcliffe, in 1930, first reported in Malaya these abnormal developments in *Hevea* cortex. The bark fissures show up externally as vertical lines on the tapping panel and at a casual glance might be mistaken for an unusual form of black-stripe disease (Fig. 40). On closer examination it will be found that the symptoms are quite different from those of black stripe, for the stripes do not spread irregularly and no fusion takes place. The lines are distinct and quite separate, usually slightly inclined to the vertical.

Sutcliffe reported on the first cases examined, that the tapping system was a single cut on a quarter of the tree on *virgin bark and the cut was about forty inches above ground-level.* He does not specially comment upon this feature, but it is obvious that, as tapping in ordinary cases is seldom started at a height of more than three feet,

and as the trees were twenty-one years old, tapping had been commenced on a panel of virgin bark above the old renewed panels.

In 1931–32, numerous estates with fields of old rubber had reached a position which was not too reassuring in respect of bark reserves. Yields were diminishing if tapping was continued on the old re-

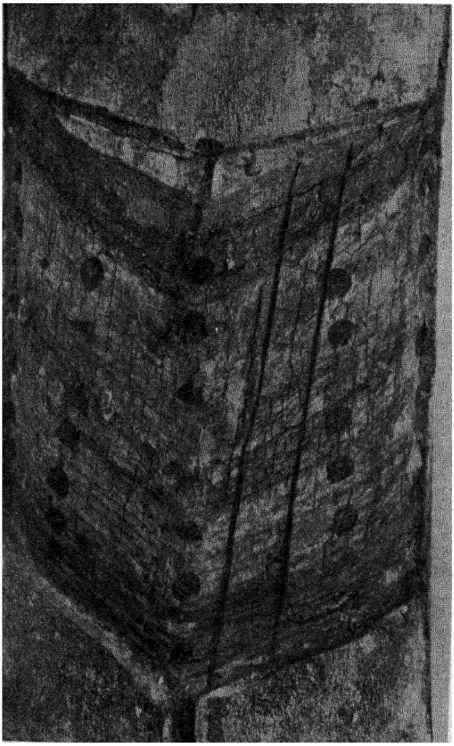


FIG. 40.—Tapping panel of old tree showing typical external appearance of internal bark fissures, running across the whole of the tapped area, slightly inclined to the vertical.

newed bark panels, so, in an attempt to keep yields at a normal level, tapping was started at a height of forty-eight inches, or even sixty inches, in virgin bark above the old renewed panels. In most, if not in all cases, the black lines now known as internal cortical fissures appeared in the tapping area opened up in the manner depicted, and the writer has never observed them except in these particular circumstances.

In most cases the lines run from the top of the tapping panel to the tapping cut (Fig. 39). In other cases, the lines begin half-way down the panel and continue down to the cut. In still other cases, the lines which completely cross the tapping panel may be followed upwards, running beneath the surface of the untapped virgin bark, while at the lower end the lines continue to run for some distance below the tapping cut. The number of lines on a tapping panel varies from one to eight; they are not truly parallel to one another but are slightly wider apart at the lower ends, being inclined from the vertical, to the right. Sutcliffe says the fissures follow approximately the course of the latex vessels.

No fungus or other organism has ever been found associated with these lines. Bobilioff described similar fissures from Java in 1927. In one case he found as many as 113 fissures on one tree.

The cause of the formation of the fissures is unknown but Bobilioff suggests that trees growing on poor soils exhibit an intense development of stone cells. The result thereof is the formation of a very hard bark, while the soft bark is thin. When growth sets in the hard bark is not sufficiently elastic, so the soft bark tears and the fissures mentioned are formed. In the meantime, the latex vessels are damaged, so that the fissures become filled with latex. The fissures are immediately bounded by a cambium, and by its activity new cells are formed, and it is for this reason that not only latex but cells also are found in the fissures. They are mostly parenchyma cells which have been transformed into stone cells.

The writer has not had the opportunity of making a careful microscopical examination of these fissures. The explanation given above does not appear to be very convincing, and judgment must be suspended until further work can be carried out upon this aspect of the trouble.

Drying-out of the Tapping Panel

Steinmann remarks that this disease is often mistaken for mouldy rot, but this is an erroneous impression, as it is a purely physiological phenomenon. It is uncommon in Malaya, as it is said to occur in the dry season only, chiefly on weak trees, or those which have been too deeply tapped; overtapped trees with poor bark renewal as a result of growing on poor soils often show the symptoms typical of this wound reaction. The patch of dry discoloured bark does not follow the line of the tapping cut as do the diseased areas in a mouldy rot attack, so there should be no difficulty in diagnosis.

Panel Damage caused by Squirrels

Large open wounds on recently tapped bark are often caused by squirrels, which eat the soft renewing bark away to expose the wood. Further reference to squirrel damage will be made in a later chapter (Fig. 69).

Panel Damage caused by Larvae of Psyche (Acanthopsyche) snelleni, Heyl.

The larvae of one or more species of Psychid moths occasionally appear in large numbers and begin to feed on the recently renewed bark in close proximity to the tapping cut. Further remarks with reference to this insect will be found later (Fig. 62).

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SECTION 3

STEM DISEASES

CHAPTER XIV

MAJOR AND MINOR STEM DISEASES

Pink Disease (*Corticium salmonicolor*)—Die-back in Rubber Trees—Stem *Ustulina*—White Thread Blight—Horse-hair Blight—Ring-Rot—Mistletoes (*Loranthus* spp.) on Rubber Trees.

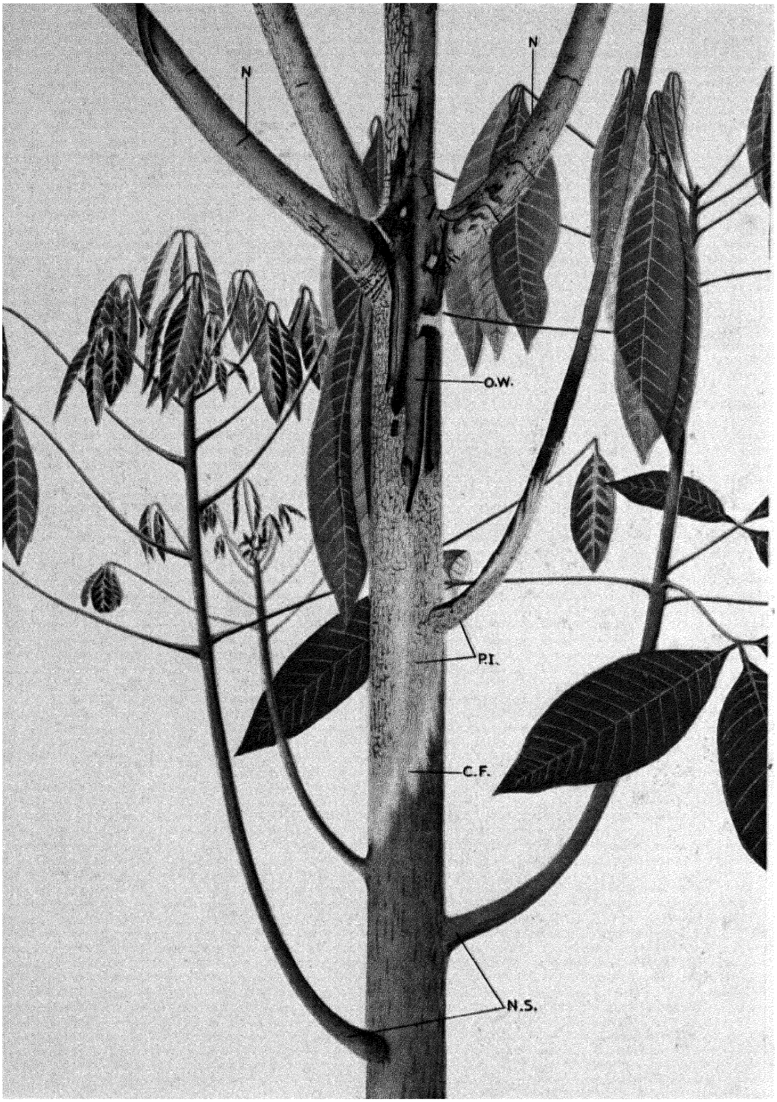
INTRODUCTION

PETCH mentions the following in his chapter on stem diseases:

(1) Pink Disease
(2) *Ustulina zonata*
(3) Death of Green Twigs
(4) Die-back
(5) *Fusicladium* Stem Disease
(6) Mouldy Rot of Tapped Surface
(7) Thread Blight
(8) White Stem Blight
(9) Horse-hair Blight
(10) Top Canker
(11) *Pestalozzia* disease of seedlings
(12) *Loranthus*

Of this list Nos. (1), (2), (6), (7), (9) and (12) are found in Malaya; No. (6) (Mouldy Rot) has been described in a previous section.

Nos. (5), (8) and (11) have not been recorded definitely in Malaya, while Nos. (3), (4) and (10) may possibly be considered as arising from similar causes, for as far as Malayan experience goes, the symptoms, as described by Petch, would now be ascribed to lightning injury or die-back following on scorching. The only important stem diseases in Malaya are pink disease, Stem *Ustulina* as it is termed, and die-back caused by a *Diplodia* sp., which fungus always appears rapidly after scorching.



Pink Disease

N = **Necator** pustules on *upper* surface **of attacked branches.**
O.W. = **Open wound** characteristic of pink disease.
P.I. = **Pink incrustation.**
C.F. = **Cobweb form** of fungus growing out from edge of **pink incrustation.**
N.S. = **New** shoots from dormant buds in healthy areas of **stem,** still **free** from the **fungus attack.**

Pink Disease

Caused by *Corticium salmonicolor*, B. & Br.

The cause of pink disease, *Corticium salmonicolor*, B. & Br., is a widely distributed fungus. It is reported to be of economic importance in other countries on different crops. In Java, coffee and cinchona are seriously affected by it and in Ceylon it causes a serious disease of tea. In the West Indies, a pink fungus on cacao, known for a long period as *Corticium lilacino-fuscum*, B. & C., owing to a misidentification, has been proved to be *C. salmonicolor*. West Indian records show that pink disease occurs in Porto Rico, Dominica, St. Lucia and Trinidad on cacao, and it has also been found there growing on other host plants.

C. salmonicolor is not only a widely distributed fungus, but it is also practically omnivorous for it has been found on so many species and genera of plants, widely separated. Rant mentions that it has been found on no less than 141 species of plants belonging to 104 genera and many different families. The fungus has been recorded on gymnosperms and dicotyledons but has not yet been recorded on monocotyledons. In Malaya, the following host plants have been listed:

Common Name	*Scientific Name*
Para rubber	*Hevea brasiliensis*, Mull.-Arg.
Cocoa	*Theobroma cacao*, L.
Coffee	*Coffea robusta*, R. Br.
Gardenia sp.	..
Hibiscus	*Hibiscus rosa-sinensis*, L.
Camphor	*Cinnamomum camphora*, T. Nees & Eberm.
Cassia sp.	..
Horse mango	*Mangifera foetida*, Jour.
Langsat	*Lansium domesticum*, Jack
Lime	*Citrus medica*, L. var. *acida*
Durian	*Durio zibethinus*, Murr.
Jak	*Artocarpus integrifolia*, L.
Belimbing	*Averrhoa belimbi*, L.
Mango	*Mangifera indica*, L.
Bush covers	*Tephrosia hookeriana*, W. & A. *Indigofera arrecta*, Benth. *Clitoria caganifolia*, Benth.

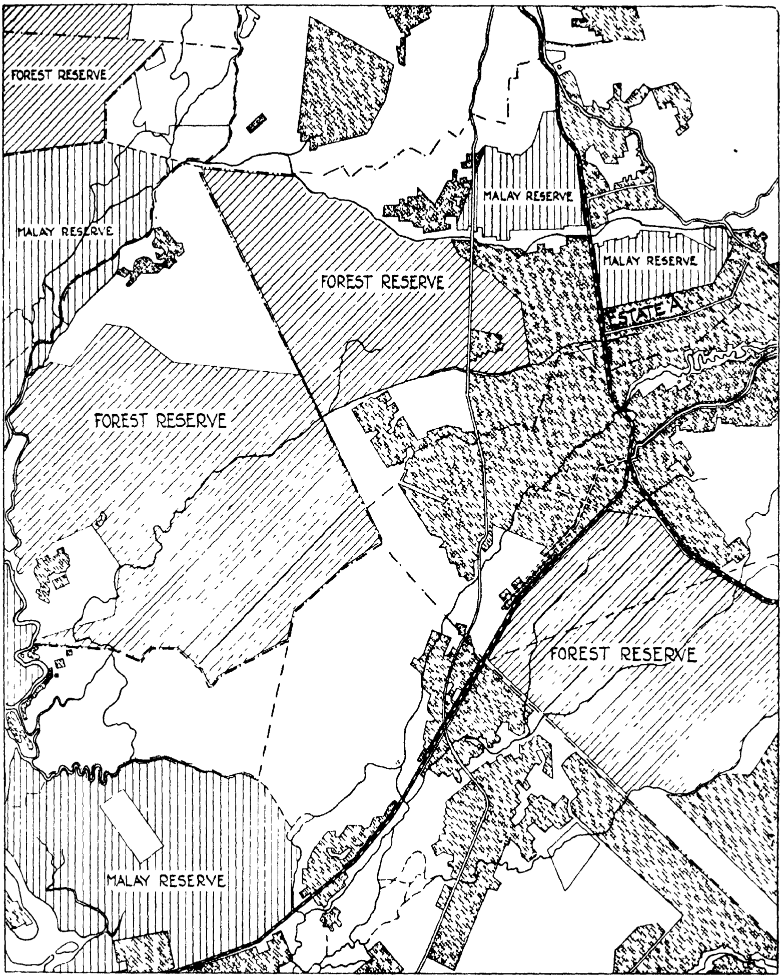
C. salmonicolor is probably native in most of the countries in which it has been recorded. Many of the plants found attacked by the fungus

in Java are indigenous and some of the plants found affected in Malaya are indigenous also. The fungus has probably spread from native hosts to plants that have been introduced, such as rubber, tea, coffee and cinchona. There is presumptive evidence that the fungus does grow on jungle trees in Malaya but there is no definite record up to date, and in any event it seems unlikely that pink disease would cause serious damage to forest trees. Unfortunately, this fungus has shown a great partiality for *H. brasiliensis* in certain localities, and as far as Malaya is concerned, this host is by far the most frequent.

Distribution.—In 1914 the chief centres of distribution of pink disease in the Federated Malay States were Southern Perak and the Northern part of Selangor, the district round Telok Anson, near Kajang, and in Kuala Selangor. At the present date every state growing rubber trees of a susceptible age has reported attacks of pink disease but it is only in certain localities, where climatic conditions favourably affect the growth and spread of the fungus, that they are serious. It is still most abundant in the districts of heaviest rainfall in the proximity of the mountain range or high hills or where large tracts of jungle still remain intact. In Malaya, it might be said that all estates where serious pink-disease attacks are met with are situated in the neighbourhood of large jungle reserves, and in the writer's opinion this is the most important feature. A line drawing (Diagram VII) is given; this is copied from an official map, which illustrates the type of situation where serious pink-disease centres are found, if the rubber areas carry trees from two to nine years of age. Estate *A*, recorded at the close of the company's financial year in 1933, that on an area of $132\frac{3}{4}$ acres, carrying a total of 17,551 trees, 10,417 were treated and 18,513 prunings were made in the systematic treatment of pink disease.

Pink disease attacks rubber trees of all ages, once the woody parts are definitely developed; a few cases may be found on trees less than two years old, but it is uncommon until after the second year has passed. From this point onwards, pink-disease attacks will, in favourable localities, increase in severity until the eighth or ninth year, even though systematic treatment may be carried on continuously. But if treatment is maintained, the disease incidence will begin to fall rapidly between the seventh and tenth year, and after the peak is passed the disease should not cause much further trouble. But if treatment at any stage is neglected there is no doubt that the disease can persist in a destructive manner up to the fifteenth or twentieth year. In such areas it may attack the main stem of twenty-year-old

trees and "ring" them at a height of ten to twenty feet from the ground. Cases of this type usually die.



RUBBER ESTATES. FOREST RESERVES.

MALAY RESERVES.

DIAGRAM VII

The following table gives actual figures obtained of the number of pink disease cases requiring treatment over the first ten years on one estate:

TABLE IV

NUMBER OF CASES OF PINK DISEASE TREATED FROM 1923 TO 1932

	Planting Years									
	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932
No. of trees treated	..	..	255	889	8524	14,298	7845	9263	20,604	2272
No. of trees cut out	..	..	..	..	..	..	1816	2074	684	
Annual rainfall	..	..	..	..	..	..	..	140″	157″	133″

Symptoms.—The external symptoms of pink disease are very variable. Four distinct forms of the fungus can be distinguished, and all four forms may be found together on diseased bark areas at the same time; or, there may be only the commonest form present, i.e. the pink incrustation, which gives the popular name to the disease.

Pink disease is so called because the fungus causes a pink incrustation on the branches or main stem and it is usually better developed on the under or shady side of the branches. When fresh, this pink incrustation is very striking and cannot be confused with any other disease of rubber trees (Plate IV). The bright pink colour fades away rapidly to a dingy white, especially if a short, dry spell supervenes, while the incrustation cracks irregularly.

The three forms, other than the common pink incrustation, are known as under:

Malaya	*Java* and *Sumatra*
(*a*) Cobweb form	Spinnegewebe form
(*b*) Pustular form	Hockerchen form
(*c*) *Necator decretus*, Mass.	*Necator decretus*, Mass.

Plate IV illustrates three forms exhibited by *C. salmonicolor*, when the fungus attacks a rubber tree. If the pink incrustation is fresh and prominent, the other two forms depicted (*a*) and (*c*), will very often be found present; (*a*) the cobweb form growing out from the edges of the pink incrustation as white or pale-pink strands of a cobweb-like nature which run irregularly over the surface, the strands sometimes being so delicate that they are easily overlooked; (*c*) the *Necator* stage consisting of orange-red (not pink) pustules, about $\frac{1}{8}$ of an inch in diameter; this form is usually found on the upper side of an attacked branch which is exposed to the brighter light.

In Malaya, the pustular form is not commonly found except when

the fungus attack has been continued for some time and the pink incrustation has lost its fresh pink colour. The pustules are minute in size, are pale-pink or white in colour and are situated in small cracks in the bark arranged more or less in parallel lines. This is sometimes the only form of the disease which can be seen externally; in such a case, it is not a simple matter to diagnose the attack correctly, without careful examination.

Method of Attack.—In *Hevea* the disease appears generally to originate at the fork of a tree or where several branches arise at the same level from the main stem. Different observers have different views as to the first signs noticeable after the fungus has successfully established itself. Petch says the first indication is usually the appearance of a pink incrustation of interwoven hyphae over the bark. If this statement may be interpreted as the appearance of the loose cobweb form of the fungus, it would then be in agreement with experience in Malaya. The pink patch gradually extends and may ultimately cover the whole circumference of the stem and the bases of the adjacent branches for a length of several feet. Such vigorous infections are seldom met with in Malaya except on estates where treatment is neglected, for the disease is practically concentrated in the side branches. Under the central part of a diseased patch the bark has usually been killed by the fungus and is brown and dry, but towards the margin it may still be alive and laticiferous. This is explained by the fact that the fungus travels over the surface of the bark more rapidly than within it, hence, although the bark is permeated by the fungus over the greater part of the patch, the advancing margin is generally superficial. The dead bark usually dries up and cracks and splits away from the wood, leaving an open wound (Plate IV). The fungus penetrates into the wood or xylem and destroys the continuity of the functional water-vessels which are situated in the peripheral region of the woody cylinder. As a result of the leaves of attacked branches being deprived of water, they shrivel up and die. Tyloses in the woody vessels are a constant feature when *H. brasiliensis* is attacked by pink disease, but these bladder-like ingrowths are commonly met with wherever branches or stems of *Hevea* are wounded. Another common feature in the early stages of infection is the exudation of latex from the affected parts which often serves to indicate the presence of pink disease to the planter.

The main seat of attack on young trees commonly lies on the stem at the places where the branches originate, and the response made by plants attacked is very typical, owing to the upward passage of the water stream being seriously interfered with. The dormant buds in

the healthy cortex below the attacked stem areas, are stimulated to activity, and numerous, healthy, adventitious branches are usually produced. Such cases can be treated very simply and effectively by pruning or pollarding the young trees below the diseased areas and removing all adventitious shoots excepting one or two which show

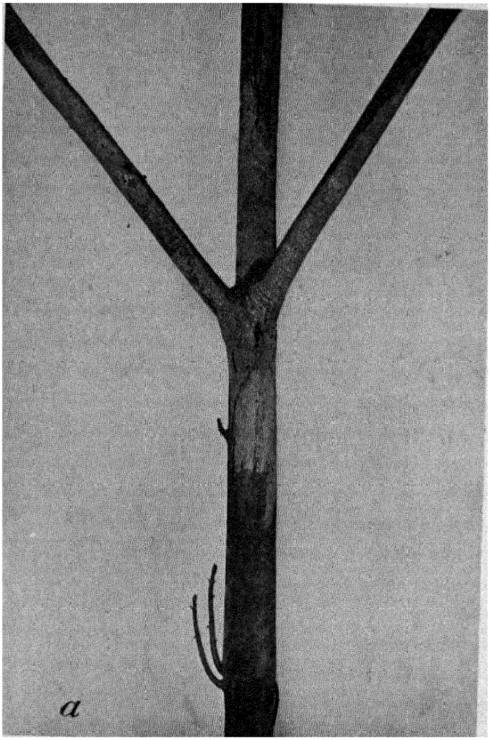


FIG. 41 *a*.—Pink disease. General features, showing pink incrustation, open wound, and new shoots from dormant buds in healthy cortical tissue.

vigorous growth. Plate IV and Figs. 41 *a* and *b* show these typical features.

Spores.—The different forms of pink disease can be subdivided into sporing and non-sporing types. The cobweb and pustular forms are non-sporing, i.e. are infertile; they are merely mycelial aggregates in and on the bark and though they do not bear reproductive spores they may aid in the spread of the disease since dead bark scales carrying viable portions of the fungus frequently flake off. This is in

fact one of the least appreciated items in control, for it can be said with a fair measure of certainty that when control operations are being undertaken, insufficient attention is given to preventing small portions of diseased bark being distributed about the plantations. This commonly happens when diseased branches are carelessly pruned.

FIG. 41 *b*.—Pink disease. Severe attack of pink disease on main stem of young tree; showing numerous new shoots arising from dormant buds.

The common pink incrustation is considered to be a spore producing type of *C. salmonicolor*, but the exact systematic position of the fungus in Malaya needs further investigation. Authorities in other countries accept the basidial spore production in this fungus as normal for the genus *Corticium*, but in our investigations in 1914, this did not seem to meet the case. The writer has never had opportunity of looking into this question since that year, and the point requires investigation. Great difficulty was experienced in finding basidio-

spores in the 1914 investigations, but this may only be a question of striking the correct developmental conditions, as is instanced in the case of *Fomes lignosus*, noted earlier in this book. In Malaya, the pink incrustation which carries basidiospores is noticeably thicker, has a more homogenous surface, and when dry, cracks into larger pieces than the sterile incrustation. The basidia, as seen in the investigations mentioned above, are scattered and irregularly arranged.

The *Necator* stage was formerly considered to be a separate fungus, and was named *Necator decretus* by Massee; it is now known to be a stage in the life-history of *C. salmonicolor*.

The name *N. decretus* was given in 1897 to a fungus which was associated with a disease of coffee in Selangor. On rubber the *Necator* stage is found in the form of orange-red pustules, each pustule being a mass of spores which serve to propagate the disease. The individual spores are irregular in shape and are hyaline when seen individually under the microscope. Each spore-mass is waxy in consistency and it is probable that the spores become separated from one another only in wet weather, when they are washed apart. When a *Necator* pustule is about to be formed, the mycelium aggregates beneath the outermost cortical layers, forming a kind of stroma, which by growth ruptures the tissues of the host. The whole of this stromatic mass becomes converted into spores by the separation of the cells one from another. The irregularity in size and shape of the spores is due to this peculiar method of spore formation. The dimensions of the spores are $14–20\mu \times 8–10\mu$.

The first record of pink disease was probably the one made in 1897; when Massee misidentified it as due to *Necator decretus*. But at later dates the fungus has been designated *Corticium calceum*, *Corticium javanicum* and *Corticium zimmermani*; as stated above, similar confusion existed in the West Indies, where the fungus was misidentified as *C. lilacino-fuscum*.

The *Necator* spore form of the fungus is much more commonly formed than the basidial stage, and it is very probable that it takes a more active part than the latter in the dissemination of the disease.

Spread.—The chief agent of distribution is the wind, for diseased bark, carrying each or any of the various forms of the fungus, easily breaks into small flakes which are blown about. The pink incrustation and the pustular forms of the fungus retain their vitality for an appreciable length of time after being detached from a diseased tree. It is also possible that red ants and other insects which visit rubber trees might carry spores and infective material from diseased to healthy trees.

Control of Pink Disease on Rubber Plantations.—Experiments were carried out in Malaya in 1914 with a view to utilising Bordeaux Mixture in the control of pink disease. The conclusion drawn from this experiment was that, in this country, the difficulties attendant on spraying tall trees with power sprayers were too great and alternative methods had to be sought. Promising results were obtained by painting over the diseased surfaces with tar, and continuing the painting two feet above and two feet below the external, visible symptoms. One month later the treated trees were examined again and, if pink disease symptoms were still evident, a second painting with tar was given. In later years, tar 80 per cent was mixed with 20 per cent crude oil, because it was claimed that the mixture could be applied more easily. These methods were generally adopted and if the monthly round was adhered to, results were satisfactory.

The frequency of treatment, of course, depends on the amount of money available and during the last few years of necessary economies, estates have not paid sufficient attention to the monthly examination and treatment. Adequate control can be maintained only if this programme is carried out. The position has not improved at the time of writing, and the disease has assumed more serious proportions on some estates than would otherwise have been the case.

Treatment by tar painting has defects owing to the variability in different shipments of tar, and when a "dud" consignment comes on the market, there are numerous complaints of serious damage due to bark burning. There is a very indifferent brand of tar being sold at the present date (1933), and during the last two months the enquiries with reference to treatment of pink disease have trebled. The trouble is nearly always the same, bark burning following on tar treatment. Other complaints have been made, even with the best-known brands; some are difficult to apply while others do not adhere properly to the infected surfaces. Tar of an unknown composition is a dangerous substance in the hands of coolies, and if bark burning is to be prevented, it is advisable to use an asphaltum-kerosene mixture, which has a known composition and can be brought to any desired consistency. The question of cost again arises, but the mixture recommended is only slightly more expensive than tar, and if solar oil is used in place of kerosene, the mixture is then slightly cheaper.

In a fair percentage of intractable cases the tar treatment has to be supplemented by pruning away diseased branches and destroying them by fire. Absolute reliance cannot be placed on any method of painting and as Petch suggested in his 1921 edition, a combination of painting and pruning would probably be the better course. Experi-

ence has proved this to be the case, but cutting-out must be carefully performed. As little as possible should be done in wet weather because of the great difficulty attached to the adequate disposal of diseased tissues. A judicious combination of pruning during dry weather and painting *only* during wet weather has been found to be the best plan in Malaya. The following schedule is recommended at the present date:

(1) During wet weather periods, a monthly round must be kept up. Diseased bark areas must be painted over with the asphaltum-kerosene mixture or asphaltum-solar oil mixture recommended below. Pruning to be suspended as far as possible.

(2) During dry weather periods the disease gang should be increased for the time being; so that a fortnightly or three-weekly round can be worked to. The branches which show symptoms of pink disease should have the diseased areas painted over with a strong antiseptic solution; a 5 per cent solution of Izal is recommended. The branch should then be cut out and destroyed by fire as quickly as possible. A strong antiseptic solution should be painted over the diseased areas in all cases before pruning in order to kill all external parts of the fungus, so that even if small flakes of diseased bark are allowed to blow about as a result of careless work, they will be harmless. This is a most important point which is often neglected.

It will no doubt be realised that modifications of the above treatment will have to be considered for individual cases, more especially if the main stem or large branches are involved, when cutting-out would result in serious loss of leaf canopy. But this must be left to the discretion of the planters who are directing the control work.

The mixture which is now generally recommended for painting treatment is as follows:

Asphaltum, (DX) brand	40 lbs.
Kerosene or Solar Oil	4 gallons
Brunolinum, Noxo or Solignum . .	2 pints

The method of mixing is detailed on page 442, where attention is drawn to the various precautions which must be observed.

Good results have also been obtained in control of pink disease by using a 20 per cent solution of Agrisol or Brunolinum Plantarium for painting over diseased areas. This treatment is simpler as there is no complicated mixing to be done, but it is more expensive.

Butler reports that Bordeaux Mixture has been used very successfully to prevent new infections in young rubber trees. It is certain the attack is due to spores, whether from jungle trees or from dis-

eased rubber trees. Hence, if the parts of the tree most susceptible to attack, such as the forks of the branches, can be coated with Bordeaux Mixture before the onset of a rainy period, the spores lodging in these places would be killed. If the mixture can be made to stick on a tree during heavy rains, considerable advantages would be gained. This was done by the addition of resin adhesive to a Bordeaux Mixture of 6 lbs. copper sulphate, 4 lbs. quicklime and 45 gallons of water. The mixture was kept well stirred and applied with a brush round the forks and for a foot or two down the stem and up the branches. The result was a reduction of the disease by 50 to 75 per cent. Some of the trees had three applications, some two, some only one. Such, in broad outline, are the results obtained in South India but, as the methods described have proved satisfactory in Malaya, no work has been carried out on these lines by the writer. Bancroft, in 1912–13, however, reports a case on one Malayan estate where spraying with Bordeaux Mixture on an area carrying trees five to six years old was undertaken. The area sprayed covered 33 acres and the spraying was confined to the forks and branches of the trees for the reason explained above. The cost of spraying materials and labour was 1·05 dollars per acre, to which the cost of the machine, 150 dollars, must be added. The results of the treatment were not recorded.

Die-back in Rubber Trees

Caused by *Diplodia* sp.

This disease is commonly known in Malaya as " Diplodia Die-back", and was recognised very early in the history of the rubber plantations in this country. It was specially investigated by Bancroft in 1911. It is found in all the rubber-growing countries of the Middle East.

Though the die-back disease has been under scrutiny for such a long period, much confusion still surrounds the life-history of the causal fungus, and there is still doubt regarding the exact status of the fungus as a parasite on *H. brasiliensis*.

Spore Forms of the Causal Diplodia sp.—In 1911 Bancroft concluded from his investigations that three different spore forms are included in the life-history of the fungus; firstly, a *Diplodia* sp. which appears to be the form destined for rapid reproduction and the parasitic form; secondly, a *Cytospora* sp. which develops on the plant some time after it has died, and thirdly, an ascigerous fructification, which he named *Thyridaria tarda*; the latter form appears later and can infect the living plant with subsequent production of the *Diplodia*

form. No supporting observations for these views were forthcoming until 1929, when Tunstall, working on die-back of Tea in India, found a few specimens of an ascigerous fungus associated with a die-back disease of tea bushes. According to Tunstall the fructifications found agreed with the description given by Bancroft for *Thyridaria tarda*, Banc. Ascospores from these fructifications were germinated and grown in pure culture and produced pycnidia, typical of *Diplodia*. In a later paragraph, Tunstall says, "This form (*Thyridaria*) has not been produced in culture, but *immature pycnidia*, typical of the *Diplodia* fungus, have been obtained from cultures of the ascospores obtained from two specimens". The supporting evidence obtained by Tunstall cannot be considered entirely satisfactory, for an element of doubt must still remain until mature pycnidia are produced in pure culture. Another point that may be noted is that Tunstall mentions only the *Diplodia* and *Thyridaria* stages of the fungus, while the *Cytospora* stage described by Bancroft is not referred to. (Since writing the above in 1933, information has been obtained which suggests that Tunstall's observations must be treated with reserve, and it will therefore avoid confusion if the *Hevea* fungus is still referred to as the *Diplodia* sp.) This is another example of the difficulties encountered in tracing the sequence of spore forms and getting exact systematic names, even for the most common disease-causing fungi in the Middle East.

Inoculation Experiments.—During the last six to eight years many interesting observations have been made which indicate that this fungus is a selective parasite and that its destructive work can only be initiated under certain conditions. If these conditions are provided, infection takes place and when the conditions favour the growth of the fungus, i.e. if the attacked trees are not too vigorous, it spreads down the branches and stems in the characteristic way conveyed in the term "Die-back". The *Diplodia* die-back fungus, while definitely exhibiting parasitic tendencies, can easily maintain a saprophytic existence on various kinds of rotting materials. In fact it is so common as a saprophyte on many different kinds of plant material, that it would be impossible to suggest any feasible cleaning-up measures if the fungus caused more serious damage than it does.

Bancroft reports successful inoculations made through wounds on seedling plants five to twelve months old. Efforts to inoculate unwounded seedlings were unsuccessful. Further inoculations were made, but beyond endeavouring to inoculate the tapping surface of trees seven to nine years old, he did not carry out experiments on mature trees.

Ward, in 1926, working under the writer's direction, performed some inoculation experiments which indicated the precise nature of the conditions governing infection. It was shown fairly conclusively that the *Diplodia* fungus responsible for producing die-back symptoms in rubber trees will readily infect a tree only if localised areas of cortical tissue have been sufficiently heated or scorched. The fungus readily penetrates the scorched tissue and enters the wood, through which it makes progress both upwards and downwards.

This species of *Diplodia* does not appear to be an ordinary wound parasite as is commonly believed to be the case, but is rather a special type of parasite which rapidly follows any damage done by scorching. In Malaya, the "die-back" fungus is always prominent in the following affections:

(*a*) Lightning damage, both on old and young trees.
(*b*) Sun-scorch of exposed lateral roots.
(*c*) Seedlings affected by excessive ground heat at the collar.
(*d*) Die-back in large snags after the budding operation is done.
(*e*) Spear-head wounds at junction of scion and stock.

A description of the affections listed above will be given in a following chapter.

The evidence obtained in Malaya is strongly supported by the description of "die-back" attacks given in other works of reference, and in the writer's opinion there seems little doubt that the *Diplodia* die-back fungus is practically harmless to vigorous rubber trees if scorching of the cortical tissues is prevented.

Symptoms.—The progress of the fungus is marked by a typical ashy-grey discoloration of the wood tissues. If a section of the diseased wood tissue is studied microscopically, dark-brown hyphae can be seen running through all the tissue elements. But the hyphae extend beyond the limits of the discoloured tissue for a distance of many inches, for they are hyaline at first and only later take on the distinctive colour (Fig. 42).

Petch describes the symptoms of die-back as follows:

In the typical case described above, *B. theobromae* enters the stem at the top through a dead green shoot. The shoot may have died from one or many causes, but in general, the fungus appears to enter through shoots which have been killed by *Gloeosporium alborubrum* or *Phyllosticta ramicola*. The fungus then grows down the stem, both in the wood and the bark but rather more rapidly in the former, and as it descends to the level of the branches it kills them, either by attacking them or by cutting off the supply of water. The wood is blackened and the cambium, with the innermost layers of the cortex, becomes a black film on the surface of the wood.

Further, he states:

The trees are generally attacked in groups, sometimes of about a dozen; one or two of these are usually killed but the others are generally in the early stages of the disease and can be saved by pruning off the dead tops.

This last quotation is an exact description for lightning damage on young rubber trees as seen in Malaya and dozens of cases have been

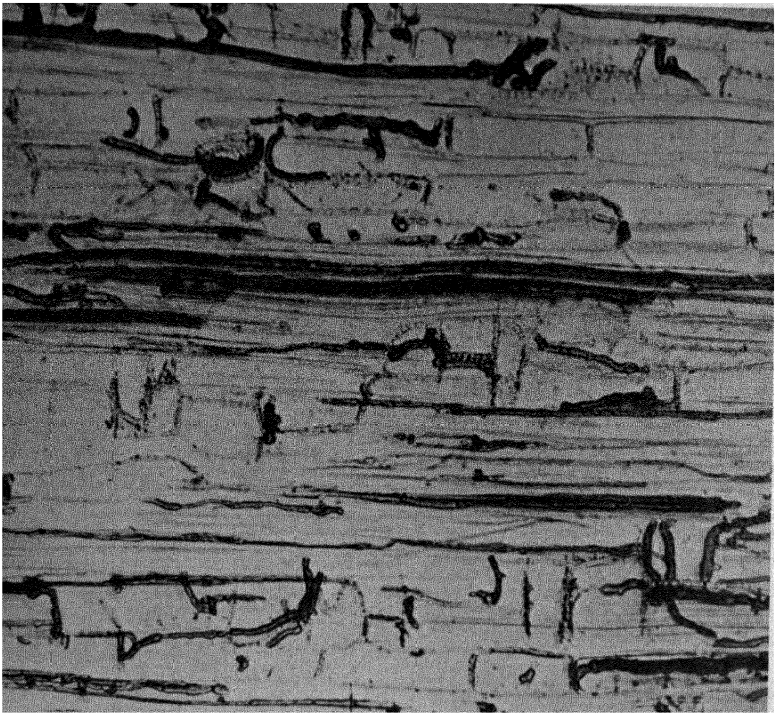


FIG. 42.—Section of woody tissue of rubber branch, showing them permeated with the dark-coloured hyphae characteristic of the *Diplodia* sp. causing die-back disease.

inspected this year (1933), which has been remarkable for the large amount of damage done by lightning in many different districts. The fungi mentioned above, *G. alborubrum* and *P. ramicola*, are not prominent, although one case recently examined showed *Gloeosporium heveae*, Petch, in abundance.

The only form of die-back which can be described as typical in Malaya is that found on steeply sloping, hilly areas which have

suffered badly from erosion, or on rubber-growing areas which have been neglected in other ways. This type of die-back is of some importance as there is a considerable acreage of such rubber scattered throughout the country. In 1926 an enquiry was made to ascertain whether the *Diplodia* fungus was the most prominent one to be seen in this particular type of die-back. Sun-scorch was suspected since the trees had their branches almost devoid of leaves, and overheating of the bare branches by the sun, could not be avoided. A random sample of 105 branches of *H. brasiliensis*, suffering from die-back was gathered; these were examined by splitting them open, and the results obtained are given below:

Typical *Diplodia* die-back cases	11
Diplodia sp. present along with other fungi or insects	22
No *Diplodia* present	72

The fructifications of many fungi are found on such die-back branches and these are included in the list of fungi which is published in this work. The collections were made by Weir and Baker. One of the fungi found most frequently on branches or woody tissue suffering from overheating, is *Polystictus hirsutus*, Fr.

Fructifications.—The following description of the *Diplodia* and *Thyridaria* fructifications is taken from Tunstall's paper:

> The common (*Diplodia*) type of fructification is the black, spherical bodies (pycnidia), either half embedded in the bark or produced in clusters, in a stroma on the exterior of the bark. The pycnidia are globose or subglobose, ostiolate and dark-brown to black in colour. In some cases, the pycnidia are covered with hairs. The pycnospores are oval or ovoid, densely granular, often very thick-walled. They are at first hyaline and continuous but afterwards they take on a yellowish-brown tinge and ultimately become dark-brown in colour and uniseptate. The dark-brown and uniseptate spores have longitudinal striations. They measure 29·5μ by 14-75μ. The spores are borne on short conidiophores and are liberated in threads through the ostiole of the pycnidium. These threads are at first white but afterwards become black. Paraphyses are present.

The only comment necessary is that in the above description, a printer's error appears to have escaped notice. The 14-75μ given for the spore measurement should probably be 14-15μ, which figure is approximately correct. The figures given by Tunstall, with this correction, agree well when compared with Bancroft's figures, given many years earlier.

> The other form of fructification, (*Thyridaria* form. A. S.) the perfect stage of the fungus, is found on the stems and exposed portion of the root

(of the tea bush. A. S.). It has so far been found on four occasions. The perithecia are immersed with the mouth projecting. The asci are cylindric—clavate, either sessile, or with a very short stalk and contain 8 spores. The ascospores are arranged in irregular rows, they are oblong, triseptate, slightly constricted at the septa, and of a dark-brown colour. The asci measure $115\text{-}150\mu \times 18\text{-}26\mu$, the ascospores measure $26\text{-}28{\cdot}5\mu \times 6{\cdot}4\text{-}9\mu$, and the paraphyses are 130 to 450μ in length.

In a preceding paragraph it is remarked that Tunstall does not mention the *Cytospora* stage recorded by Bancroft. He points out, however, that sometimes the black spots on the bark, which mark

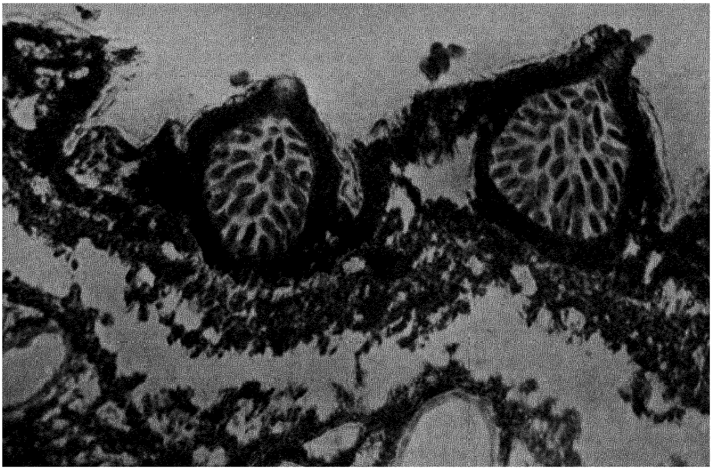


FIG. 43.—Section showing *Diplodia pycnidia* produced on stroma, and containing spores.

the position of the pycnidia, are fringed with a white, chalky powder, and that this is commonly the case when the bushes are growing in a heavy, stiff clay soil. This white substance, he states, is the mycelium and chains of spores of another fungus, possibly parasitic on *Thyridaria tarda*. Petch makes a similar record as occurring on the tea-bush in Ceylon. He says the white fringe which appears round small clumps of hyphae or extruded spores on the roots consists of masses of minute, globose, hyaline spores, 1μ in diameter with hyaline hyphae 1 to 2μ in diameter, on which conidia are borne laterally or on finer lateral branches. Whether this is a stage of the *Diplodia* sp. or a hyphomycete parasitic on the latter, has not been determined.

For the purpose of completeness, Bancroft's description of the *Cytospora* sp. recorded by him is given:

Cytospora.—Pycnidiis submembranaceis, atris, ovatis, stromate atro ruguloso immersis, ostiolo prominulo (30 microns lato), donatis, 200-250 × 180-200 microns; sterigmatibus copiosis, 22-24 × 3 microns; sporis ellipticis, hyalinis, 3-4 × 1·5-2μ.

Reference to a recent paper by Shear must now be made. He reports that Saccardo, in his *Sylloge Fungorum*, gives *Diplodia* as the pycnidial form of species of *Cucurbitaria*, *Massaria*, *Otthia*, *Melanomma*, *Pleospora*, *Thyridaria* and *Gibberidia*, and remarks this is not a complete list and probably other genera could be given. He further states that his studies show that at least such highly developed forms as those usually referred to *Diplodia* may occur in such widely separated genera as *Tryblidiella*, *Physalospora* and *Cucurbitaria*, and that parallelism of this sort evidently occurs in other cases. The mention of the genus *Tryblidiella* is interesting to investigators in Malaya, for the writer has occasionally found a species of this genus on dead branches, while Ridley records *Tryblidiella rufula*, Sacc., being found on dead branches in Singapore. While some uncertainty exists as to whether the records from Malaya refer to dead branches of rubber trees, there is no doubt as to *Tryblidiella leprieurii* (Mont.), Sacc., occurring as a saprophyte on dead branches of *Hevea*, in Ceylon. This appears to afford a convenient starting-point for a further investigation in respect of the *Diplodia* complex.

Distribution.—The fungus responsible for *Diplodia* die-back is very widely distributed and has been recorded from almost every country in the tropics. Petch remarks that owing to the incompleteness of description and the highly variable nature of the fungus, it has received an extraordinarily large number of names. A list of synonyms is appended:

Botryodiplodia theobromae, Pat.
Macrophoma vestita, Prill. and Del.
Diplodia cacaoicola. P. Henn.
Lasiodiplodia nigra, Appel and Laubert
Lasiodiplodia theobromae, Griff. and Maubl.
Botryodiplodia elasticeae, Petch
Diplodia rapax, Massee
Chaetodiplodia grisea, Petch

Treatment.—The only treatment which can be recommended is to cut out and burn the diseased tissues. The cut must be made through healthy tissue, nine to twelve inches beyond the limits of obviously diseased tissue. In young plants, one to three years old, suffering

from lightning damage, the limit of diseased tissue is usually indicated by the shooting of lateral buds and the trees can be pruned or pollarded at the level indicated by these buds just as in the case of treatment of pink disease on young trees, where the same feature is commonly met with.

STEM USTULINA

The root diseases caused by *U. zonata* first gained prominence in Malaya in 1914–16, and a full description of symptoms, growth and the structure of the fungus is given in the section devoted to root diseases. In those days it was noted that this fungus could function as a wound parasite in any part of the tree system, particular attention being called to a case of "stag's-head" in a rubber tree, in which fructifications of *U. zonata* were found developing luxuriously on small wood branches not more than half an inch in diameter. Stag's-head in rubber trees is usually attributed to an attack of the common die-back fungus, *Botryodiplodia theobromae.* While the position was clearly established in 1917, South, in 1927, directed attention to the increased prevalence of *U. zonata* on the stems and main branches of rubber trees on several of the older rubber estates, especially in the coastal districts of Selangor.

In such cases as the above, where the stem or main branches are affected, the attack usually commences at a spot where a wounded surface is present, owing either to the careless pruning of a lateral branch, to damage caused by wind, or by an accident such as the falling of one tree against another when thinning-out is in progress.

Stem attacks by this fungus in Malaya, may (*a*) follow on attacks by boring beetles, or (*b*) enter the stem tissues through large wounds caused by the breaking of the main branches which results in the exposure of a large, rough wood surface. Collar attacks might come under the category of stem attacks, for there is little doubt that the starting-point of many collar attacks is behind the pad of old, oxidised rubber which commonly accumulates at the base of old trees.

Boring Beetles and U. zonata.—The association of *U. zonata* with attacks by boring beetles is dealt with later, where it is pointed out that the food of the larvae is a fungus growing upon the walls of the burrows of the adult beetles, and that the fungus develops from spores carried in the stomach of the female. In 1916 the writer isolated *U. zonata* from boreholes made by these insects, and attention was directed to fructifications found in the conidial stage, the upper flat surfaces of which showed undoubted insect tracings. These observations are of some interest as indicating the possibility

of *U. zonata* being a fungus commonly carried by the so-called "ambrosia" beetles.

Method of Attack.—In the writer's experience, the favourite seat of infection is a large, uneven surface of exposed woody tissue such as a wound on a main stem where a large branch is broken away by wind. But Petch points out that, in Ceylon, it is very noticeable that attacks by *Ustulina* usually occur on diseased or damaged areas on which the previously damaged bark has remained more or less *in situ*, i.e. has not fallen off and exposed the wood. This is very probable, for as pointed out above, a common starting-point of an attack at the collar is beneath or in close proximity to pads of coagulated rubber which have accumulated at the base of the stem. The cortical layers covered by these pads of rubber cannot function normally, and owing to their unhealthy condition, probably form very suitable places for infection by *U. zonata*.

When stem infection takes place through a wound formed by the breaking of a large branch, there is after a time a copious exudation of latex which coagulates on the bark around and beneath the wound. These large pads of coagulated latex are the most prominent feature in this type of infection, when conditions favour the rapid growth and development of the fungus. The fructifications of the fungus often develop prolifically in stem attacks; cases have been met with where the fructifications extended in a continuous sheet for a distance of over two feet, the plate being about nine inches to fourteen inches wide (Fig. 9 *c*).

When large branches are attacked they should be cut out as early as possible. The first cuts should always be made on the under side close to the trunk or larger branch from which it is being removed and should penetrate to about one-third of its thickness. The branch should then be cut through from the upper side at a point a few inches further out than the cut on the under-side. As a heavy branch nearly always falls before it is cut completely through, this method prevents it from tearing a strip of bark and wood out of the trunk or larger branch to which it was attached. No "hat pegs" should be left, but all branches or stubs of large branches cut off in the manner described above should be removed at their junction with another branch or with the main trunk, and the wounded surface should be smoothed with a sharp instrument and be thoroughly tarred or covered with an ashphaltum mixture at once. Further dressings of the exposed surface with these preparations may be given at intervals. Wounds caused by winds or accidents should also be smoothed off with a sharp instrument and care should be taken to leave no hollows

in which water can collect. Such wounds should also be dressed at intervals with the wound covers.

White Thread Blight

White Thread Blight is of common occurrence on cultivated trees other than rubber. As the name implies, the external appearance of the fungus is very similar to strands of coarse thread, white in colour, running over and closely adhering to the surface of attacked branches, ascending the leaf-stalks and frilling out to finer threads on the surfaces of the leaves, which become as a result closely matted together.

These white threads are mycelial or rhizomorphic strands, and they represent the vegetative phase of the fungus. The mycelial strands vary considerably in size and may run long distances over the branches. When the fungus reaches the smaller twigs and leaves, the latter die as they become matted together, and the mass of dead leaves and twigs stands out prominently.

Brooks states that the white thread blight is very variable in character and it is possible that more than one species of fungus is involved. Largely because the fungus has never caused any serious damage to rubber trees in Malaya, no critical work on this particular line has been accomplished, so the position has not yet been clarified up to date.

Bancroft described the white thread blight of Para rubber and Camphor in 1911; since that time only one record of a fruiting stage has been made. A notable feature of most thread blights is that fructifications are but rarely produced and the single collection in Malaya was made by Richards, who forwarded it to England for identification. It was named *Cyphella heveae* by Massee. Further fructifications should be examined before the name is considered finally settled.

In Northern India, tea-bushes are attacked by a thread blight, while it has been reported on rubber from all Eastern rubber-growing countries.

The thread blight growing on rubber trees is spread through the plantations by diseased leaves carrying portions of the mycelium being blown about and coming to rest amongst the branches or foliage of healthy trees. Petch states that cases can often be found where a dead leaf, or the remains of it, are seen adhering to the stem at the point where the thread starts. If trees are so closely planted that their leaves are in contact, it is obvious that the fungus could very easily pass from a diseased to a healthy tree. It is in such over-

crowded situations that the fungus could cause a certain amount of damage. A case was recently examined in which trees, two years of age, were covered with a thread-blight fungus at the base, extending from ground-level up the stem to about six to nine inches in height. In this instance the threads were more silky than usual, and the fungus formed a prominent white, silky layer over the whole circumference of the stem. A close examination was necessary to make certain the strands were not those of *Fomes lignosus*.

Treatment.—Cut out and burn diseased leaves and branches.

Horse-hair Blight

Caused by *Marasmius equicrinis*, Mull.

This fungus is only rarely met with in Malaya. It takes the form of mycelial cords, black in colour, which resemble black horse-hair in appearance. The name, horse-hair blight, includes the mycelia of many different species of fungi, in the same manner as thread blight. The mycelial cords found on rubber trees are round, smooth and more or less polished. They do not adhere closely to the branch along their whole length as described for the mycelial cords of white thread blight, but are attached only at certain points by small brown pads of mycelium. It does not always pass from the branch to the leaves *via* the leaf stalk; it may pass across from stem to leaf, or from one branch to another by means of long, free cords, and large numbers of twigs and leaves may become involved.

Petch states that this fungus is common on tea-bushes in Ceylon, and is frequently found on rubber trees interplanted with tea, more especially at the base of the stem up to a height of one foot from the ground. It is not parasitic, but lives on the dead brown bark scales.

The writer has not found the fructifications on rubber trees in Malaya, but Petch states that it is a small, mushroom-like fungus named *Marasmius equicrinis*, and that it is rare on the mycelium which overruns the higher parts of a plant but is frequently present on the black cords at the base of rubber trees. It is more common on rotting *Hevea* fruits which have fallen to the ground, in Malaya.

Ring Rot

This curious disease was first described by Keuchenius, in Sumatra. In Malaya, the writer has seen only a few cases. The affection is characterised by the drying-up and peeling-off of concentric black zones or rings (Fig. 44). It is reported that in the dry season the

disease is usually dormant and will recur when the rainy season sets in. When in the active state, if the outer cork layer is carefully removed, the bark shows a sepia-coloured discoloration outside the ring-like pattern. The discoloration is only superficial and has not been found to reach the cambium. It may reach a depth of about half

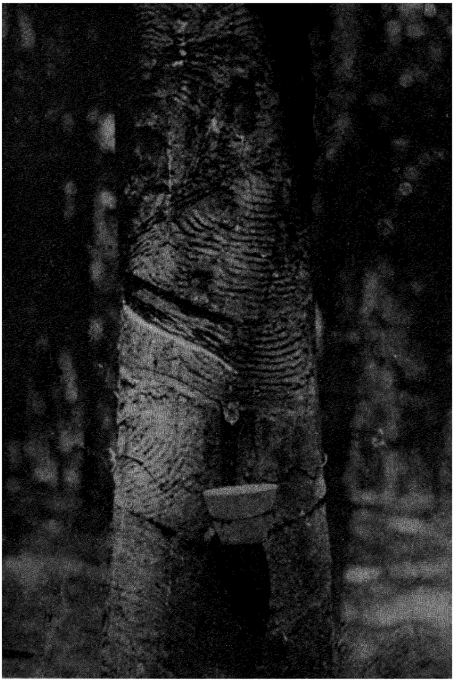


FIG. 44.—Tree affected by ring-rot. External scaly bark scraped away to show typical concentric rings.

the bark thickness and some latex containing bark may be spoiled thereby.

The causal agent of the disease has not yet been determined. If affected trees are found, the discoloured bark should be scraped away.

MISTLETOES (LORANTHUS SPP.) ON RUBBER TREES

The semi-parasitic plants of the mistletoe type are well represented in Malaya, and are commonly seen growing on all types of dicotyledonous plants. Only a few species are recorded from rubber trees.

Occurrence.—In 1911 Bateson recorded the occurrence of a species of *Loranthus* growing on rubber trees in Pahang, whilst in 1914 Brooks gave an account of two species of *Loranthus* attacking rubber trees in Negri Sembilan. The latter investigator mentions that one of these mistletoe species was also found growing on a common melastomaceous plant, presumably *Melastoma malabathricum*, L. (= Kedudok.). In 1924 Sands described the five species of mistletoe which are the chief pests of cultivated trees in Malaya. These are:

(1) *Loranthus ferrugineus*, Roxb.
(2) *Loranthus pentandrus*, L.
(3) *Loranthus grandifrons*, King
(4) *Loranthus pentapetalus*, Roxb.
(5) *Elytranthe globosa*, G. Don.

Of the above list, (2) and (5) are commonly found on rubber trees in Malaya; (1) rarely so, while (3) and (4) have not been recorded as growing on rubber trees up to date. Recently, two new records of mistletoes growing on rubber trees have been made:

(6) *Loranthus crassipetalus*, King
(7) *Loranthus casuarineae*, Ridl.

L. crassipetalus is a somewhat uncommon species, while *L. casuarineae* is usually confined to Casuarina trees, which are commonly grown in Malaya.

Mistletoes are green-leaved, evergreen, shrubby plants with a special seed mechanism which enables them to become attached and to grow on woody, dicotyledonous trees; they are seldom found on monocotyledonous trees such as bamboos and palms. They are parasitic in that they are dependent on the host plant for the provision of water and nutrients from the soil, but they are not completely parasitic since they possess green leaves, and are able to perform their own function of converting water and carbon dioxide into organic food materials, i.e. carbohydrates, by means of the energy derived from light. Owing to the fact that they can manufacture their own carbohydrates they do not make such serious demands on the host plant as would otherwise be the case. Hence these semi-parasitic plants do not usually destroy their hosts rapidly unless the latter are in extremely poor condition, when the infestation may be a very heavy one.

The sticky fruits are one-seeded, succulent berries usually bright coloured or white, with a fleshy exterior and a mucilaginous interior. The seed has a very sticky, gelatinous coat, which enables it to

adhere closely to any surface with which it comes in contact. This gelatinous covering can absorb water from rain, mist or dew, so that the seed does not perish rapidly under unfavourable conditions. Further, it is the only means by which the seed, on germination, obtains the water necessary for growth until the haustorium or sucker has penetrated into the water-conducting tissues of the host plant.

It is practically certain that birds which feed on the berries are the chief means by which the seed is disseminated. Observations in other countries have shown that birds, after feeding on the pulp of the berries, wipe their beaks against the branches of trees in order to rid them of the sticky seed, which is distasteful; they may also void on to branches with their excrement any seed swallowed. Other possible agencies for dispersal are (*a*) heavy rain which beats down the fruit, (*b*) high winds and the natural fall of ripe berries from higher to lower levels of the host trees.

Method of Attack.—The seed on germination puts out a short, stout cylindrical root-like body, the hypocotyl, which, on coming into contact with the bark of the host plant, swells out at its free end into a disc and forms what is known as a holdfast. From the central or lower portion of this the haustorium or sucker develops, which is capable of penetrating to a considerable depth into the tissues of the host by means of solvent ferments and the pressure resulting from growth. After the supply of water and food has been made secure by the haustorium, the young shoot develops rapidly.

The haustorium in forcing its way through the bark destroys this during its passage, and eventually penetrates the wood and forms a close organic connection between the wood vessels of the host so that water and raw food materials can be readily obtained.

As growth proceeds, a rounded, swollen mass of tissue forms over the place where the holdfast was attached to the host plant. The swellings may be small but are sometimes very large. In the species *L. pentrandus*, occurring on rubber trees, large masses of hypertrophied tissue occur at points where the primary and secondary haustoria enter the host and they become knobby and warty with age (Fig. 45 *b*); in *E. globosa*, the primary and secondary swellings where haustoria enter the host are small or absent, and in *L. ferrugineus*, the swollen masses are small in size.

Secondary haustoria are mentioned above. In all species of *Loranthus* and *Elytranthe*, secondary branches arise at the original point of infection, also secondary branching roots, or runners, which travel for considerable distances along and around the infested branch in

different directions (Fig. 45 *a*). At frequent intervals, haustoria are formed along the side of the root-runner nearest the branch; on large branches they are formed about every 1½ inches or more, on smaller twigs about every ¼ of an inch, and they enter the host-branch almost

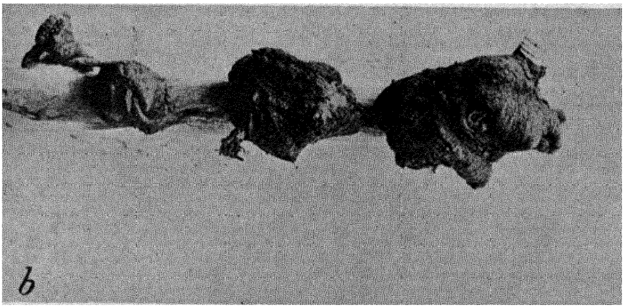


FIG. 45.—(*a*) General view of mistletoe on branch of rubber tree. Note the "runners" of the mistletoe plant. (*b*) Showing large masses of hypertrophied tissue formed on rubber branches where haustoria of *Loranthus pentrandus* enter the host.

directly below the place of formation. In this way, a tree deficient in vitality may become heavily infested from a single seed.

The haustoria continue to expand and multiply as growth proceeds. Eventually, the end of the branch of the host is killed as a result of the continued withdrawal of water and inorganic food materials by the parasite. In cases where the attack is a very heavy one, the whole tree may be so weakened that it dies outright.

Sands reports that certain of the local species of mistletoe can parasitise each other; for example, *L. ferrugineus* has been found growing on *L. pentandrus*, *E. globosa*, *E. barnesii* and *Viscum articulatum*, while *V. articulatum* has been frequently observed on *L. pentandrus*, *L. ferrugineus*, *E. globosa* and *E. barnesii*. But the most unusual case was one in which a durian tree (*Durio zibethinus*) was attacked by *E. barnesii*; on this mistletoe *V. articulatum* had attached itself, while *L. ferrugineus* was growing on *V. articulatum*.

Generally speaking, the parasites are found on the higher and outer branches of the trees they attack; that is, in places where they obtain plenty of light. They do not, as a rule, thrive under dense shade, hence cultivated trees which are in poor condition suffer more severely than those in good health. Vigorous mistletoe attacks on rubber trees in Malaya have been found only in neglected fields of rubber. Brook's specimens, obtained in 1914, were reported as having been obtained from neglected rubber fields. In recent years, rubber estates on the east coast of Malaya, which were severely affected by the unprecedented floods of 1926, have been attacked by these semi-parasitic growths and they are quite commonly found on estates in Kelantan.

Treatment.—Branches supporting the semi-parasitic bushes should be cut away, and an attempt should be made to reinvigorate the trees by improving soil conditions. It is obvious that simply cutting away diseased branches from debilitated trees will not improve the position to any great extent, unless due attention is given to the necessity of increasing the vigour of the plants so that they may withstand further reinfection.

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SECTION 4

LEAF DISEASES

CHAPTER XV

MAJOR AND MINOR LEAF DISEASES

Leaf-fall caused by *Oidium heveae*—South American Leaf Disease; Abnormal Leaf-fall in Burma, South India and Ceylon; *Gloeosporium* spp.—Bird's-eye Spot—Shot-hole Leaf Disease; Rim Blights—Leaf Spotting—Sooty Moulds—Diseases of Green Twigs—*Phyllosticta ramicola* and *Gloeosporium alborubrum*.

INTRODUCTION

NUMEROUS fungi have been reported as causing a certain amount of damage on the leaves of both seedling and mature rubber trees, but only three serious leaf diseases have occurred throughout the world. These three diseases are known as:

(*a*) South American Leaf Disease, caused by *Melanopsammopsis ulei* (Henn.), Stahel.
(*b*) Leaf-fall caused by *Phytophthora meadii*, McRae.
(*c*) Leaf-fall caused by *Oidium heveae*, Steinmann.

The South American leaf disease is confined to the Western Tropics, having been reported from Brazil, Peru, British Guiana, Surinam and Trinidad. It has not yet been reported from the rubber plantations of the Middle East.

The abnormal leaf-fall, (*b*) above, has been reported from Ceylon, South India, Burma and Java, according to Petch; Steinmann says, however, that leaf-fall caused by attacks of *P. meadii* have not been found in Java; neither has it been reported from Malaya, up to date.

Oidium leaf-fall has been reported from Ceylon, Malaya, Java and Sumatra, but not from the rubber-growing districts of India and Burma.

Leaf-fall caused by *O. heveae* is the only leaf disease of importance in Malaya, but the other two cause serious losses in the countries where they are present, the South American leaf disease being so severe that it prohibits the profitable development of rubber plantations. For this reason, a short account of the two leaf-fall diseases not yet reported in Malaya will be given.

In addition, there is a fairly long list of rather indefinite leaf affections known as leaf spottings and rim blights. The following list is compiled from Petch's last edition with small alterations:

Common Name	*Reported Casual Fungus*
(*a*) Mite attack	Associated with *Gloeosporium albo-rubrum*, Petch, or *Gloeosporium heveae*, Petch
(*b*) Bird's-eye spot	*Helminthosporium heveae*, Petch
(*c*) Shot-hole leaf disease	Several fungi are found associated with this type of affection
(*d*) Listed from S. America	*Catacauma huberi*, P. Henn.
(*e*) Rim blight	*Ascochyta heveae*, Petch
(*f*) ,, ,,	*Sphaerella heveae*, Petch
(*g*) ,, ,,	*Guignardia heveae*, Syd.
(*h*) Disease caused by the Alga	*Cephaleuros mycoidea*, Karst.
(*i*) Sooty moulds	Species of *Capnodiae*

Colletotrichum heveae, *Phyllosticta heveae* and *Pestalozzia palmarum* have also been recorded growing on leaves of *Hevea*. Of the above list, only (*a*) and (*b*) can be considered of economic interest in Malaya. With reference to the remainder, only short notes will be made in this section, for the position in Malaya in relation to these fungi is so ill-defined that they can be considered only of slight interest. The association between the spider attack and *Gloeosporium* and *Helminthosporium* species of fungi is dealt with under *Oidium* Leaf-fall.

LEAF-FALL CAUSED BY OIDIUM HEVEAE, STEINMANN

The first recorded appearance of this disease was made in the Malang district of West Java by Arens in 1918. In 1925 *Oidium* leaf-fall was reported from Ceylon, and in the same year the writer first recorded the disease in Malaya.

In all these countries the *Oidium* leaf-fall disease has assumed serious proportions, requiring active combative measures on a large scale and at considerable cost. Between 1925 and 1929 there were no records of *Oidium* leaf-fall in Malaya, but in 1929 the disease became apparent in many districts, and from that year annual outbreaks have been reported, that for 1930–31 being most virulent. The virulence of the disease is largely dependent on climatic factors and so the intensity varies accordingly; if the climatic conditions

favour the spread and growth of the fungus, or happen to be such as to cause a slow refoliation after wintering, a serious outbreak will be the outcome. In the same way, soil conditions may be such that the trees are lacking in vigour and, as a result, a slow refoliation takes place; more serious outbreaks occur on these places than on areas where soil conditions are normal. Thus, when making a comparative statement in any particular year full allowance must be made for the influence of climatic and soil factors. For instance, Sanderson stated in 1930 that "the appearance of the *Oidium* mildew on *Hevea* in Ceylon was first noted in 1925 and since then the area and intensity of attack have both steadily increased", but Murray, in Ceylon, says in 1931, "*Oidium* attack has not increased to any serious extent since the disease was first reported in Ceylon in 1925". This statement suggests, as will be shown later actually to be the case, that the limiting factors for spread and virulence are very definite. The correct attitude to take up is to realise that once the fungus has become established, it only needs favourable conditions for a virulent attack to ensue and *vice versa*. There is little doubt that in Malaya there is a tendency towards a considerable spread in the affected area between the years in which virulent attacks occur. The fact that the *Oidium* leaf-fall fungus is well established in Malaya and can carry on from one season to another until a favourable season supervenes, is, to say the least, disconcerting.

Causal Fungus.—*Oidium heveae*, Stein., belongs to the group known as the "powdery mildews" (*Erysiphaceae*); this group contains many species which are obligate parasites and cause many destructive diseases. *O. heveae* is an obligate parasite, and the delicate, hyaline, cobweb-like mycelium usually develops on the surface of leaves, forming a more or less superficial covering. This statement is made by Steinmann, but in Malaya, a complete covering is uncommon. Beeley has successfully photographed an extraordinary dense growth of the *Oidium* fungus on the midrib of the leaf (where the conidiophores and chains of conidia were so dense as to be in contact with each other), and yet to the naked eye the growth was only visible when observed in certain angles of light, A slight, glistening, furry surface could then be distinguished on an otherwise smooth leaf (Fig. 46 (*a* and *b*)). This finding differs from certain advanced cases reported from the N.E. Indies and Ceylon, where the fungus spots on the leaves resemble "whitewash" spots. But in the Kalutara district of Ceylon, Murray reports that the leaf symptoms are similar to those in Malaya, where the fungus is not easily visible, and occurs generally in spots on, or in close proximity to, the leaf veins, the

favourite position being on the midrib on the under surface of the leaf. Being found chiefly on the under-side of the leaf, the fungus is always shaded from the midday sun.

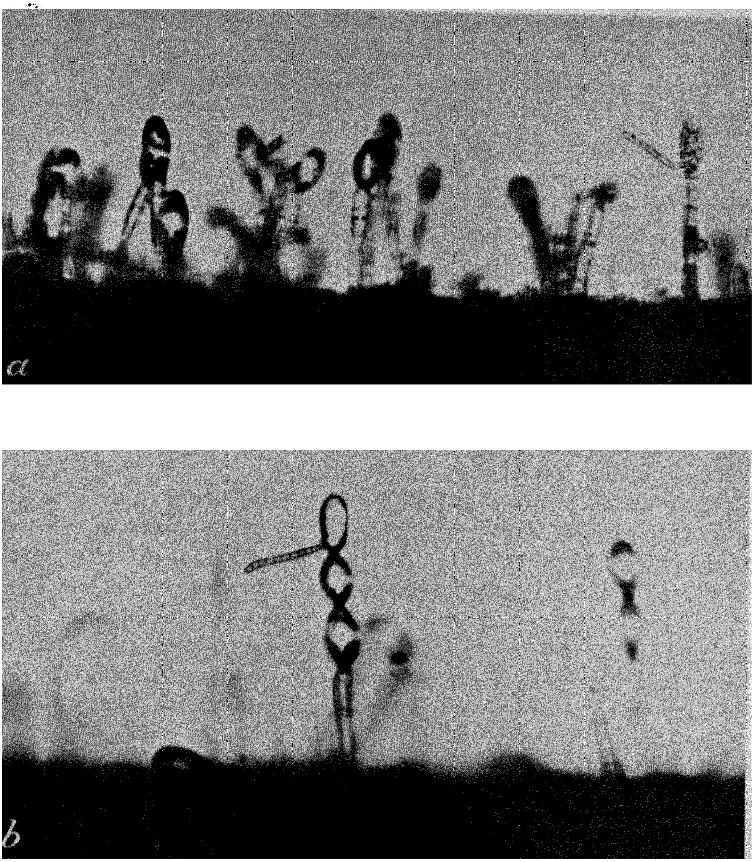

FIG. 46.—(*a*) Showing dense growth of *O. heveae* on leaf vein, with a spore germinating *in situ*. × 300. (*b*) Illustrating the spore chains produced by *O. heveae* on infected leaves. × 300. Note top spore of chain germinating *in situ*.

When the spores germinate on the leaf, they first form attachment organs, the *appressoria*. Later they produce a surface mycelium. Branches of the surface hyphae penetrate the cuticle and special haustoria or absorbing organs grow into the epidermal cells. These bladder-like haustoria are confined to the epidermal cells, and

draw the food-supplies of the fungus from the cell contents of this layer.

Spores (conidia) are usually produced in abundance on short, erect conidiophores, and they are chiefly responsible for the characteristic powdery appearance. The spores are distributed by wind, insects or other agency, but are short-lived, so that if conditions are unfavourable for spread, the disease is soon checked.

Symptoms.—The attack of mildew in mature rubber is always most pronounced on young leaves, during and immediately after the wintering season. The young leaves in the bronze, greeny bronze, and later, pale-green stage, are particularly liable to attack. Young rubber or seedlings in nursery beds had not been reported as being attacked in Malaya, by this fungus, until 1933, although Reydon reported in 1925 that in East Java the mildew has appeared on the budding beds or nurseries of 17 per cent of the estates reporting attacks.

In the case of young foliage the leaves become more or less dull in appearance, as contrasted with the shining appearance of healthy leaves, crinkled from the tip, and later, a portion, commencing at the tip, becomes bluish or purplish-black in colour.

These changes apply to the leaves both in the bronze and early green stages. The leaflets soon fall to the ground and become shrivelled in appearance. The mycelium and spores can be best seen near the midrib on the under-sides of the leaves. In cases of severe attack the ground may be covered with a carpet of decaying leaves, and the retention of the more or less bare leaf-stalks on the trees, almost denuded of leaflets, is a striking characteristic. The next flush of leaves may be attacked in the same way and fall to the ground long before they are mature. It is obvious that several repetitions of such a leaf-fall during any one season may have serious consequences. Attacks on mature leaves have not been very noticeable in Malaya, and Beeley reports that "the mildew fungus usually attacks only young leaves half an inch to two inches long". However, investigators in Ceylon and the Netherlands East Indies report attacks on mature leaves which are not very severe as compared with attacks on young leaves, and attacked mature leaves frequently remain attached to the leaf-stalks. The exact nature of the stimulus which brings about the leaf-fall response to the fungus attack may probably be explained as follows. The attack by *O. heveae* results in the destruction of the cuticle and epidermal cells. As a result the water-regulating mechanism is seriously interfered with and comparatively large quantities of water vapour are lost through the diseased leaves.

In order to prevent greatly increased losses of water, the leaves are disarticulated and fall to the ground.

In Malaya the attack of mildew on the flowers is of considerable interest. An active, sporulating growth of the fungus can usually be found occurring on the flowers and flower-stalks even when, owing to recent rains, there is considerable difficulty in demonstrating the actively sporulating stage of the fungus on the leaves. It may be presumed that the natural hirsute condition of the flowers affords a means of protection from the elements, and incidentally a means of carrying over infection from one flush of new leaves to the next, despite occasional heavy showers of rain in the meantime. The ultimate effect of a severe floral attack is a huge reduction in the amount of matured seed. In one case, not a single young fruit could be seen during a prolonged tour in the infested areas, and last year (1932) an approximate estimate of the reduction in seed harvest was attempted on estates where sulphur dusting with power machines was in operation. The estimate indicated a reduction from 100 to 4 per cent. Few inflorescences remain on a tree when there is a severe floral attack, and even if they do remain attached, very few open to maturity. Further, early wintering trees may fail to set any fruit at all, while later wintering trees, though bearing a heavy flush of flowers, may be so heavily infected that few if any ripened seeds are finally produced from the flowers. One of the main effects of a mildew attack lies in the seed harvest and lack of seed for future planting programmes is a matter of some consequence.

Leaf Damage confused with Oidium Leaf-fall.—During 1933, in answer to a questionnaire, a large number of estates reported *Oidium* leaf-fall and sent in specimens for examination. Of these specimens, 25 per cent could not be diagnosed as *Oidium*; for the damage was done by an insect and resulted in the production of malformed leaves, very similar in appearance to those attacked by *O. heveae*. The damage was caused by a small, very quick-moving "Attid" spider, which weaves a web round the triplets of very young leaves. Leaves so bound together in triplets form between them an ideal damp chamber for the development of leaf-spotting fungi of the *Helminthosporium* and *Gloeosporium* types. These fungi cause the death of the leaf-tips, which later are torn apart by the wind and appear very ragged as a result. Leaves damaged in this way are usually malformed, the tips discoloured and badly torn, while even healthy parts may be eaten away and badly spotted.

Other leaf-eating insects are also fond of the shelter provided by the bound leaves, and are responsible for further damage. A weevil,

Phytoscaphus leporinus, Faust. (Fam. *Anculionidae*), is the most commonly found in such cases, while the common mite, *Tarsonemus transluscens*, Green, is also frequently observed within the sheltered leaf chamber.

This spider pest has been active particularly in young, immature rubber, one to six years of age, in Selangor, Perak, South Kedah and South Johore. It seems to prefer a rainy season, but is much less dependent on climatic conditions than is *O. heveae*.

Mites and Oidium Leaf-fall.—Sanderson reports that mites have been found on some occasions in association with *Oidium* attacks, but it by no means follows that the attack by the fungus must be preceded by mite attack. At a later date, Beeley points out that mites were present only in advanced stages of the disease, when the mildew fungus was difficult to find and when decomposition had set in. Apparently healthy, young, green leaves and also flowers were observed to be heavily infected with the fungus, while mites were entirely absent. As *O. heveae* is an obligate parasite, its requirements for successful growth and development are but the cell conditions of the host plant as regards turgidity and the necessary climatic conditions. It is possible that the association of these insects and the fungus is met with merely because they both show their greatest development under similar conditions. It may further be mentioned that the most effective treatment for mildew is also the chief means of combating mite attack.

Gadd reports from Ceylon that another fungus has been found on many of the older *Hevea* leaves examined for the presence of *Oidium*, namely, a species of *Cicinnobilis* which is parasitic on the *Oidium*. This fungus has oval, usually stalked, brown or yellow-brown, cellular pycnidia, measuring $34\text{-}40\mu \times 24\text{-}28\mu$; the spores are hyaline, oblong oval, $6\text{-}8\mu \times 3\text{-}4\mu$. On such leaves the *Cicinnobolis* is more easily found than the *Oidium*, and no doubt it helps to keep the latter in check. *Cincinnobolus* has not yet been recorded from Malaya. It is also interesting to note that the fungus causing the South American leaf disease is commonly parasitised by another fungus, a species of *Botrytis*.

Factors affecting Spread.—As a result of laboratory experiments, Beeley believes that under Malayan conditions an *Oidium* spore, when freed, must quickly alight upon a suitable host-substratum, germinate and become attached to its host, in as short a time as possible, if it is to survive and multiply so as to produce a disease of epidemic nature. Extreme conditions, high or low temperature, dry or wet atmosphere, cannot be favourable to an epidemic spread of the

disease. It has been found that for the optimum growth of the fungus and optimum production and germination of spores the following conditions are necessary:

(1) A temperature not lower than 56° F. and not higher than 62° F.

(2) A percentage humidity of 75 to 80 per cent.

(3) Suitable living tissues on which to grow.

Observations show that fresh young rubber leaves, two to three inches long, the turgidity of whose cells are such as to afford the most easy ingress of the feeding organs of the surface mycelium, are most suitable.

It has been generally understood that the amount of rainfall has some considerable influence on the incidence and spread of this disease, but reference to the rainfall figures in certain infected districts in Ceylon and Malaya shows that the differences in rainfall totals are not so great as would cause such a vast difference in amount of disease and leaf-fall. This point regarding total annual rainfall and total atmospheric humidity has been referred to previously when discussing black-stripe disease. It is the nature of the rainfall which seems of most importance. In the case of *Oidium* leaf-fall frequent light showers may have no appreciable effect on the spread of the fungus, while infrequent heavy rains definitely retard the rate of growth and spread of the fungus.

Heavy rains may influence the course of the disease in many ways:

(1) By causing the fall to the ground of ripe spores which may have developed during the interval between storms.

(2) By stimulating a more rapid growth of the buds and young leaves of the trees, so that the latter rapidly assume a condition of turgidity and maturity, unfavourable to the penetration of the fungus.

(3) By reducing the range of temperature changes; a more moderate day temperature being experienced during a period of heavy rains, while in dry weather the temperature ranges are greater, and high day temperature with comparatively low night temperatures are the rule.

(4) By reducing the humidity range for a few hours following the storm. Showery weather will, however, maintain this condition over longer periods, and hence humidity conditions more favourable to the fungus obtain.

Two definite effects of rainfall can be deduced from the statements made above, viz.:

(*a*) That rainfall may influence directly the conditions which favour the growth of the fungus.

(*b*) That rainfall directly influences the growth of the host tissues, more especially in the matter of rapid refoliation.

Field observations in Malaya definitely show that (*b*) is of the greater importance, in that the induced rapid refoliation considerably reduces the period of time over which the leaves are susceptible to attack. In this respect, *O. heveae* resembles the fungus causing South American leaf disease, for Stahel reports that young leaves lose their susceptibility to infection seven days after bursting from the bud.

An example of the manner in which rainfall influences the incidence of the disease may be interesting. The Uva district of Ceylon, in April 1920, registered only 4·25 inches of rain, with nineteen wet days, an average of 0·22 inch per wet day. These light rains produced a slow growth of young leaves, and by preventing high midday temperatures favoured the growth of the mildew fungus; consequently a bad outbreak of *Oidium* leaf-fall was experienced. In the same month of the same year, twenty wet days in Kuala Lumpur yielded 10·01 inches of rain, an average of 0·5 inch per wet day. The heavy rains in Kuala Lumpur district probably prevented an epidemic spread of the disease by inducing a rapid growth of the young leaves to maturity, thus reducing the period of time during which the leaves are subject to infection. In 1933 the great majority of reports of the occurrence of the disease came from estates having three to six inches of rain in February and between three to six inches in the first half of March. Normally there is a large increase in the rainfall in Malaya in the month of April, and the result of sufficient supplies of rain water to the soil is a rapid renewal and growth of leaf, so that the mildew fungus has but little opportunity of causing fresh infections. The April rainfall figures for many years past show that the heavy rains during this month tend to prevent any further considerable activity on the part of the fungus; the spread of the disease ceases although the active fungus can always be found on some of the more immature leaves and flowers. It may be that the growth of the leaves during wet weather is so rapid that the mildew fungus has little chance of striking the optimum conditions necessary for growth, development and spread. The fact that the rainfall has a far greater effect on the rate of growth of the leaves is of greater importance than the actual influence of the rainfall on the mildew fungus itself. Other factors affecting the retention of moisture in the soil will also have some influence.

The two meteorological factors of temperature and humidity are those which are chiefly responsible for the absence in Malaya of any

serious epidemic of this disease. This country normally experiences a very dry midday period and a damp night period, although the water-vapour pressure in the atmosphere remains more or less constant in the rubber-growing districts of Selangor. This is due to the tremendous difference between day and night temperatures, viz. 91° F–70° F. As already mentioned, laboratory tests have shown that the fungus is subject to rather definite limits of temperature and humidity for the optimum germination and growth of the spores.

In the Malay States the temperature is at all times usually above what is considered the maximum limit for optimum growth. This assumes even more importance when considered in conjunction with the figure showing the hourly changes in humidity for the respective states, which indicates that for only about one hour in the morning, 9 to 10 A.M., and for less than two hours in the afternoon, 4 to 6 P.M., is the humidity value suitable for optimum activity of the fungus.

Alor Star, in Kedah, has the lowest rainfall of all Malayan recording stations in the months of January and February, the total rainfall being only about 0·5 inch during these months. According to preconceived ideas, this district should be more subject to *Oidium* leaf-fall than any other. The rubber trees are often without leaves for several weeks during this intensely dry period, yet no reports of *Oidium* leaf-fall have so far been reported. Reference to the temperature and humidity records offer the most reasonable explanation for this. Both these factors show big variations in the twenty-four-hour period, with the result that temperature is always unsuitable, while humidity is favourable to the growth of the fungus for only one hour in the morning, 8 to 9 A.M., and about one hour, 7 to 8 P.M., in the evening, the actual period varying slightly according to the period of the day during which rain falls.

Thus there are three factors in Malaya which will largely ensure rubber trees remaining comparatively free from attacks of *O. heveae*. They are:

(*a*) Unsuitable temperature conditions.

(*b*) Unsuitable humidity conditions.

(*c*) Advent of heavy rains in April which ensures a rapid growth of young leaves during the refoliation period.

The rubber districts in Malacca have suffered more from *Oidium* leaf-fall than those in other parts of Malaya. In general, the soils in the Malacca area are in poor condition, considerable areas now carrying rubber trees having been opened up on old "lallang" (*Imperata arundinaceae*) and tapioca areas. The soils are now in an

exhausted condition and the trees look poor and definitely lacking in vigour, with the result that they cannot renew their leaves as quickly as those in other districts where the soil is in better condition. A similar statement has been put forward regarding the upland rubber districts of Ceylon, where tea has been grown for many years previously, in many cases the tea having been interplanted with the rubber. Malayan experience has shown that rubber trees on virgin soils well preserved from soil wash recover their new leaves more rapidly than those on land previously heavily cropped, where the soil is now poor as a result of erosion. In 1933 the whole of the Malacca territory suffered more severely than others with the exception of the inland district around Batang Malaka, though Chabau near by had quite an appreciable attack. Further, at the end of August some of the estates in Malacca reported a second *Oidium* attack. An inspection showed that the disease was present only in those trees which were wholly or partially refoliating. There is usually an appreciable number of trees which do not winter during the usual Malayan wintering period, February–March, but do so in the second drought period of the year, August–September. It has already been mentioned that the recognised time for wintering in Java is August. Observation has shown that in particular years 15 per cent of the trees in a mature clearing do not winter or only partially winter at the recognised time in March. This second outbreak, at the time of writing (1933), appeared to be prevalent only in the districts of Malacca and North Johore, and was confined chiefly to trees close to small clearings caused by elimination of trees suffering from root disease.

The optimum conditions for growth and germination of the spores of *Oidium heveae*, i.e. for epidemic spread, are:

(*a*) Suitable young plant tissues.

(*b*) Rainfall not too heavy during the refoliation period.

(*c*) Atmospheric temperature around 60° F.

(*d*) Atmospheric humidity in the neighbourhood of 75-80 per cent.

The climates of the high level rubber-growing districts of Ceylon, Java and Sumatra more nearly approach these optimum conditions than does that of Malaya, where most of the rubber is grown only at comparatively low altitudes and hitherto has remained comparatively free from the disease. With regard to Java, attention has been directed to the correspondence which has passed between the Rubber Research Institute of Malaya and the Director, Proefstation, West Java.

The outbreak of *Oidium* leaf-fall in both Ceylon and Malaya in the same year (1925) is of some interest. No special comments are offered

on the outbreak in Malaya, but Gadd's remarks may be given for Ceylon. He states:

It is a point of some importance that the disease in Ceylon occurred almost simultaneously in most of the rubber growing districts at points widely separated. This would indicate that the fungus was already widely distributed here on some unknown host plant, and that it was not a recent introduction from abroad. If recently introduced, the disease would have spread from definite centres, places to which the disease had been brought with introduced plants. Usually a species of *Oidium* parasitic to plant life is unable to live saprophytically, so that one must look for mildews on other plants, particularly allied plants, as the probable source of infection for *Hevea*.

Petch has published (*Anns. Perad.* VI. pp. 243-244) a list of thirty-one plants on which species of *Oidium* have been found in Ceylon, and it is possible that the fungus from one or more of these has adapted itself to a new host. When the attack of *Oidium* was first reported on *Hevea* from Java, he tried to infect *Hevea* seedlings with the mildews from *Euphorbia hirta*, Linn., and *Phyllanthus niruri*, Linn., two common weeds belonging to the same natural order as *Hevea*, but without success. This line of enquiry, however, is worthy of further investigation.

Normally, at the time when *Hevea* is putting forth its new leaf, weather conditions in Ceylon are dry, and are not favourable for fungus growth. In 1925 there was more rain and the number of wet days was greater than usual during February and March in the rubber districts, and it is probable that these wetter conditions favoured the fungus and helped the process of adaptation to its new host. If so, given normal climatic conditions at the time new leaves are next produced, it is unlikely that the trees will be severely attacked, as what infectious material has persisted on the old leaves will be shed with them on wintering. If reinfection then occurs, it must happen under unfavourable conditions and from an external source unless the fungus proves itself able to overwinter on the *Hevea* twigs. Consequently, given dry climatic conditions at the time of production of new leaves it is not expected that the disease will recur to any serious extent. But as the fungus belongs to a genus which contains a number of species causing very serious plant diseases, a careful watch should be kept for the recurrence of this mildew on *Hevea*.

The position in Ceylon is evidently very similar to that in Malaya.

Control of Oidium Leaf-fall.—Sulphur dusting by means of power dusters is regarded as the most suitable means of control for *Oidium* leaf-fall. The application of sulphur dust depends mainly on the weather, i.e. it can only be done successfully when it is dry. Four types of machine have been used in Malaya for sulphur-dusting purposes. These machines are included in the following list:

(1) Bjorklund power duster.

(2) Carl Schlieper Handel mij Holder Motor Duster Sulphia III.

(3) Drake and Fletcher's Dustejecta.

(4) Craven and Co.'s New Tornado power dry sprayer.

It has been emphasised that really heavy rain or complete lack of rain prevents the disease assuming an epidemic form. The fungus appears to be so dependent upon young leaf tissue that little benefit can be expected from dusting before the new, young leaves begin to appear. Having efficiently dusted the buds and young leaves the sulphur may be expected to provide a prophylactic effect for a period of about seven to ten days, if there is no fall of heavy rain during that period. It is of little advantage to dust during wet weather, for not only is it difficult to apply the sulphur powder, but having done so, it will be washed off by the rain in a few hours leaving the leaves unprotected.

Dusting should be commenced only when the young leaves are in the earliest stages of attack. A severe wintering will most likely indicate a rapid and more uniform refoliation, in which case only a brief and intense attack need be expected, and two or three rounds of dusting will probably give adequate control. A slow, desultory wintering indicates an indistinct season, showers of rain instead of definite drought, and then is the time to expect a heavy *Oidium* attack.

The reasons for this are as follows:

(*a*) Comparatively cool, moist conditions obtain for the growth of the fungus.

(*b*) Slow wintering and slow refoliation gives time for its spread and for its action upon the leaf.

(*c*) Suitable young leaves are available over a long period.

In most plantations it is noticeable that the older rubber suffers most, and even in such areas only patches of a few acres in extent may be affected sufficiently heavily to warrant dusting. Thus, only selective dusting of the worst areas need be attempted, such areas being singled out for dusting during the actual period of refoliation.

The adoption of correct methods of cultivation in rubber plantations, so as to ensure the maintenance of vigour of the trees, must necessarily be a first item in the treatment of this disease.

Recent experiments in Malaya, on sulphur dusting, indicate:

(*a*) That more efficient control is obtained by dusting five pounds of sulphur at intervals of seven days than by dusting seven to ten pounds at intervals of ten days. The ten days' interval proved too long for this year's (1933) sudden, brief and intense attack.

(*b*) Early and late season dusting is of little, if any advantage. It is necessary to dust during the refoliation period, when the mass of leaves are in the young stage.

(*c*) An economic area for treatment by one gang of labourers and one machine is about 2000 acres per season, when five rounds of treatment are carried through at the rate of five pounds per acre.

At 1933 prices, the cost worked out at a little over two dollars per acre, including share of costs of machine and European supervision. Owing to a recent move which has been made there is a possibility of the price of sulphur being considerably reduced, and if this materialises the costs would not be more than about 1·50 dollars per acre. A detailed estimate of costs is given at page 311.

Any recommendation for expensive treatment demands some consideration of the likely benefits to be derived therefrom. Repeated defoliations would certainly result in decreased latex yields, and sulphur dusting may be expected to prevent this to a certain extent. But the amount of decline to be expected in yield is a matter of conjecture and it is not possible to make an exact statement as to the exact increase in yield which will follow dusting. At present the only statement that can be made is that in some cases yields have improved slightly as a direct result of dusting. The results of experimental dusting carried out in 1933, in Malaya, show that foliage and bark and slightly improved yields may be expected, while benefits from additional shade to the soil will result in a better soil flora, which in its turn will tend to benefit the trees. Murray, working in Ceylon, has published certain figures relative to dusted and undusted areas, and the comparison indicates a relative increase of 221 lbs. per acre per annum in favour of the dusted field. He emphasises that, in this case, a strict comparison is not valid, but is of opinion that it is an increase of this order of magnitude. In a private communication Murray says that at a height of 2000 feet in Ceylon there is a 100 per cent defoliation in certain districts and, on such estates, fifteen pounds of sulphur per acre have had to be used as against the five pounds per acre recommended in Malaya. The estimation of the value of these factors is, however, very difficult and requires further investigation.

However necessary dusting may be from a pathological point of view, it is not yet decided whether or not the operation is economically sound at present commodity prices, i.e. *before restriction*. In many parts of Malaya, conditions are suitable to rapid growth of rubber trees throughout the year so that they may escape the disease or, when slightly infected, may themselves be able to overcome it and completely recover. In some parts of the country, however, e.g. certain districts of Negri Sembilan and Malacca, where conditions of soil and climate are not too favourable for the growth of rubber trees, it is well worth while considering dusting on a limited

scale. Large estates could derive benefits from one machine each; smaller estates might combine and utilise one machine jointly, in each case the worst affected areas being selected for dusting. If the desired benefits are derived from this limited treatment it can, in future years, be extended as required or as further funds become available.

All seed gardens and bud-wood multiplication nurseries should be dusted with sulphur as a routine practice so as to maintain continuous protection of such valuable material, not only from *O. heveae,* but from other fungi and insects capable of causing damage to rubber leaves, buds or flowers.

The present-day power machines used in sulphur dusting, while tolerably effective, will no doubt be improved upon in the future. At the present time considerable care must be taken to prevent the finely divided sulphur becoming ignited, and the danger with a petrol engine is obvious. In tropical countries the operation of dusting, if efficacious, possesses so many advantages over spraying, especially in the case of tall trees, that the latter could not be recommended. The operation is, in no way, dependent upon the proximity of water supply, and as the material is easily transported labour costs are comparatively low. A fine, dry dust may remain suspended in the air for an appreciable time, and this is an important factor in distribution (Fig. 47).

A drawback to sulphur dusting is the action of the chemical on the eyes, but this does not appear to effect seriously the coolie labourers.

For the carriage of the power dusters, the best type of suspension is shown (Fig. 48). With this type of slinging it has been found that the carriers can move about quite freely, even on steep hills. Four coolies carry the machine, while another six are engaged in carrying the sulphur powder to refill the machine as the dust is blown away. The dust-cloud will be carried to a distance of 100-150 yards by air currents, and this drift determines the line of the return journey.

The sulphur used in the dusting experiments is obtained through agents, from the Kawab Puteh Works, Java. Two grades are exported; a very impure grade known as Mud Sulphur, containing about 65 per cent sulphur, and a purer grade known as Flotate Sulphur, containing 95 per cent sulphur. A form of sulphur, known under the trade name of Olite, has been put on the market by the Imperial Chemical Industries (Malaya), Ltd.; it contains a "spreader" (mellinite) which prevents agglomeration, and the machine is less likely to suffer from clogging.

The real differences between the various sulphurs is found in their

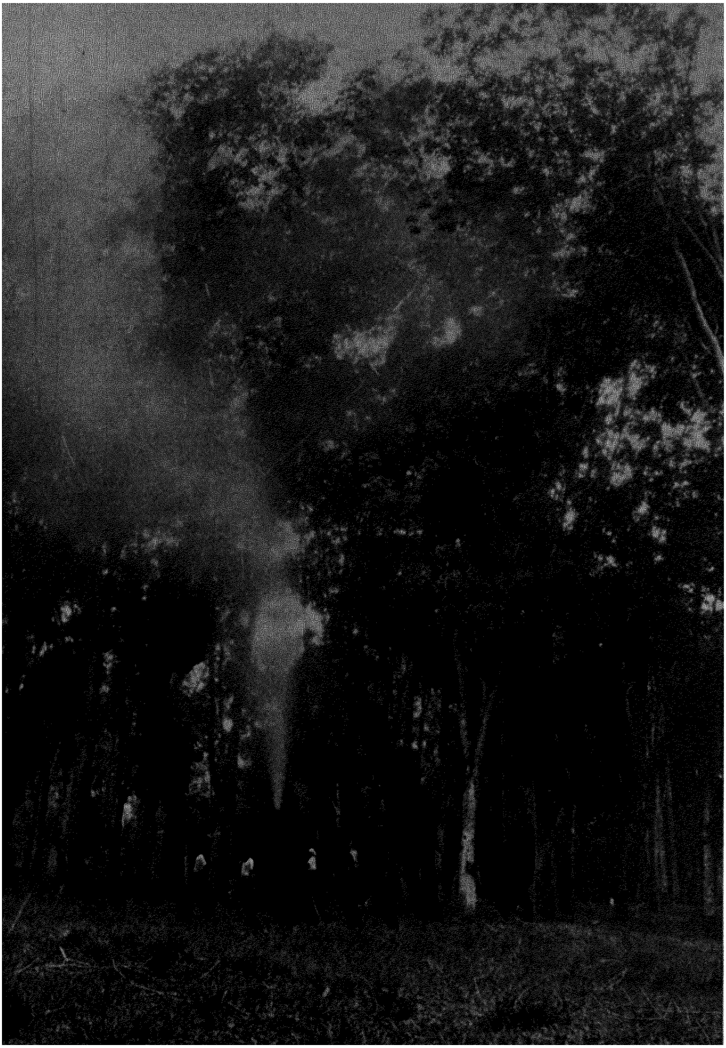

FIG. 47.—Showing Bjorklund motor duster in action. Note drifting cloud of sulphur dust overhanging the tops of the trees.

mechanical properties, i.e. water-absorbing properties, formation of hard agglomerates or pellets of sulphur, and lumping or caking during storage in the normal Malayan atmosphere. Olite sulphur, though it

lumps slightly, does not form agglomerate particles to any great extent, and can be dusted, therefore, without being previously dried in the sun. Flotate sulphur is the next best and is quite as good as Olite, providing it can be dried for an hour or so in the sun before use. Mud sulphur is not appreciably worse than the other two, but it is essential to dry it before use, otherwise much of the sulphur is

FIG. 48.—Showing type of slinging found most suitable for transporting heavy machines over rough ground.

wasted in the form of agglomerates or pellets which fall to the ground immediately after leaving the machine.

The cost of the various sulphurs in past years has been of the order: Olite, 144 dollars per ton; Flotate sulphur, 107 dollars per ton; Mud sulphur, 90 dollars per ton. The large difference in prices almost prohibits the use of Olite, and as labour costs for drying the flotate or mud brands are comparatively small, about one dollar per ton, there does not seem to be much advantage to be gained by its use. It is in the lack of drying before use that Olite sulphur gains any advantage over the other brands mentioned, while it has a definite disadvantage in being liable to ignition and explosion.

Costs of Dusting.—The following costs are computed on the basis of the maximum economical capacity of any one of the four machines named herein, i.e. the Tornado Power Dry Sprayer, the Bjorklund, the Holder Sulphia III and the Dustejecta, each having a similar capacity of 2000 acres per season, dusted five times at intervals of seven days:

	$ c.
Oil, petrol—100 gals. @ 78 cents per gall. . .	78·00
Lubricant—10 galls. @ 2·45 dolls. per gall. . .	24·50
	102·50
Labour, 12 coolies for 36 days @ 40 cents per day .	172·80
Depreciation, say 33⅓ of cost of machine . .	250·00
European supervision	125·00
Total . . .	649·30

Rate per single dusting = 6·5 cents (approx.)

Total cost of treatment = 6·5 *times the number of dustings given plus cost of the weight of sulphur desired per acre in cents.*

Dusting five times at the rate of 7 lbs. Flotate sulphur per acre.

Price of sulphur 4 cents per lb. will cost $6{\cdot}5 \times 5 + 4 \times 7 \times 5$ cents,
$= 32{\cdot}5 + 140$ cents
$= 1{\cdot}73$ dolls. per acre

Similarly 5 dustings at 5 lbs. per acre will cost 1·32 dollars per acre, and 3 dustings at 7 lbs. per acre will cost 1·05 dollars per acre.

Costs will show slight variation according to local prices of commodities and labour, while difficult land and unsuitable weather may also put up costs.

Note.—Provision must also be made for drying the sulphur—say 1 dollar per ton.

South American Leaf Disease

The fungus causing this disease, *Melanopsammopsis ulei* (Henn.), Stahel, occurs on wild species of *Hevea* in the forests of Brazil, Peru, British Guiana and Suriname. The history of the disease in rubber plantations is instructive as illustrating the difference between the incidence of disease on a single species when scattered in a natural way in the forest, and when collected together artificially as in rubber plantations. It shows also the advantage that may sometimes be gained by growing a crop plant away from its native country, outside the range of its natural parasites, but it also indicates the dangers attendant on the introduction of rubber plants from outside countries.

Nowell gives a short account, which is reproduced here, of the detailed investigations made by G. Stahel, in Suriname:[1]

The attack on the leaves begins when they are very young, and, as they develop, yellowish spots with a grey layer of conidia on the under side become apparent.

The central part of the larger spots dries up and falls away leaving a ragged perforation. On fully grown leaves the surface becomes thickly sown with black dots, and on old leaves these have developed into rounded black slots interspersed with several or many ragged holes surrounded by a black ring.

The fungus attacks the petioles and young internodes, but much less frequently than the leaves. On the petioles the check to growth on one side may cause curvature or spiral twisting; on the internodes swollen canker-like patches are produced. The inflorescences and fruit may also be infested.

The Fungus.—The causative fungus *Melanopsammopsis ulei* (Henn.), Stahel, has three forms of fructifications, viz. free conidiophores, pycnidia, and perithecia. The conidial form of the fungus was named *Fusicladium macrosporium* by Kuijper, and *Passalora heveae* by Massee; it was regarded as pertaining to the genus *Scolecotrichum* by Griffon and Maublanc, a conclusion with which Stahel agrees. The conidiophores when young are short, unicellular, brown hyphae thickened at the base, penetrating the epidermis from subepidermal mycelium; this form appears on the young translucent leaves. On somewhat older leaves, the conidiophores are many-celled, elongated, and arise from a pseudo-parenchymatous base. The conidia are formed singly and terminally, measure $20\text{-}65\mu \times 8\text{-}12\mu$, normally are divided into a wider basal cell and an elongated terminal cell, and are more or less bent or spirally twisted.

The pycnidial form was first described as *Aposphaeria ulei*, Hennings. The pyncidia occur freely as small black dots on the surface of leaves, one to two months old, mostly on the upper side. They are roughly spherical, with an apical pore and little or no trace of a papilla. The pycnospores are $5\text{-}10\mu$ long, 2μ wide at the ends, narrowing to 1μ in the middle.

The perithecial form was described by Hennings as *Dothidella ulei*, but is placed by Stahel in the *Sphaeriacea*, in the new genus *Melanopsammopsis*. The perithecia begin to take the place of the pycnidia some two months after the leaves are full grown. They occur in rings of three to four millimetres, or rounded groups of one to two millimetres in diameter, are smooth, carbonaceous, and closely resemble the pycnidia in form and size. The ascospores are hyaline, two celled (one larger than the other), constricted at the septum, $18\text{-}22\mu \times 6\text{-}8\mu$.

A species of *Botrytis* is common as a parasite of the fungus in all its stages.

Infection.—The conidia germinate in water in one and a half to two hours and cannot withstand more than fifteen to twenty hours' exposure in a

[1] Stahel, G., 1917. "De Zuid-amerikamsche Hevea Bladziekte", *Bull. No.* 34, *Dept. Land, Suriname.*

desiccator. Stahel found viable ascospores to be rare, and unable to withstand more than four to six hours of desiccation. According to his observations, the pycnospores germinate very weakly and appear to have no part whatever in the spreading of the disease, nor do the ascospores exhibit more than weak powers of infection.

The conidia produce germ-tubes which penetrate the cuticle and give rise to a sub-cuticular hypha, from which branches pass between the cells of the epidermis and produce an intracellular mycelium. Infection takes place only in the very young and tender organs. Leaves are most susceptible in the first four days after the opening of the buds, and lose their susceptibility after seven days' growth. The first sign of infection is a yellowish spot which appears in about five days, and one or two days later the conidial stage appears, followed by pycnidia ten to twelve days after infection. On the fully developed leaves the pycnidial fructifications at first predominate, succeeded later by the perithecia.

Contrary to experience with most diseases, infections are most abundant in dry clear weather, and least in rainy weather, This is attributed by Stahel to the more favourable conditions for penetration provided by an all-night coating of dew than by intermittent wetting from rain, owing to the fact that the process requires some ten hours for its completion.

Effects of the Disease.—Severe infestation of the young leaves causes defoliation of the trees, and infestation less severe, hinders the growth of the leaves and reduces their efficiency. The production of rubber is in consequence reduced, and should the defoliation, as frequently happens, be repeated, a severe die-back sets in, and the process may eventually result in the death of the top or of the whole tree.

Control.—No practicable means of control has been found. For spraying to be effective the young leaves would need to be coated at least twice during the first four days, which is more difficult to arrange for since the trees in a plantation come into leaf in a scattered way, and even different parts of the same tree do not come into leaf all at the same time. Moreover, the way the young leaves hang makes them difficult to cover.

Stahel has proposed keeping the trees artificially bare of leaves for three or four weeks to prevent the formation and dissemination of conidia, and has also suggested the use of smoke clouds at night to prevent dew formation, a method practised in vineyards against threatened frosts.

Abnormal Leaf-fall in Burma, South India and Ceylon

Petch suggests, in the 1921 edition of his book, that two species of *Phytophthora*, viz. *P. faberi* and *P. meadii*, can cause the abnormal leaf-fall which occurs in Burma, South India and Ceylon, and states that the most important difference between the two species from the economic point of view, lies in the effect of the fungus on the trees. If the leaf-fall is caused by *P. faberi*, the latex yield is not notably affected, but when the leaf-fall is caused by *P. meadii* the yield falls off enormously and it may not be worth while to tap. McRae finds

that the *Phytophthora* which occurs on *Hevea* in South India is probably the same fungus as that which is reported from Burma and has named it *Phytophthora meadii*; it is said to be the cause of fruit-rot, leaf-fall, die-back and black thread, but apparently not the claret-coloured canker. Petch discusses the systematy at some length, but the position seems still very indefinite in view of Thompson's findings that, in addition to *P. faberi* and *P. meadii*, two other species, *P. heveae* and a *Pythium*, have been isolated from naturally occurring pod-rot, in Malaya.

This abnormal leaf-fall caused by a species of *Phytophthora* results in the fall of mature, fully formed leaves, though Petch records that in 1917 and 1918 the first cases of leaf-fall occurred at the end of January, shortly after the new leaves appeared, and that in both these years heavy abnormal rains occurred at that time in some districts instead of the usual dry weather. The fall of mature leaves does not occur either in the South American leaf disease or in the leaf-fall caused by *Oidium heveae*; in both these diseases only young, newly developing leaves can be infected by the fungi concerned, and only young, immature leaves fall to the ground. As reported above, in the account of the South American leaf disease, the leaves are most susceptible to infection by the fungus four days after the opening of the buds and lose their susceptibility after seven days' growth.

Severe outbreaks of either pod-rot or abnormal leaf-fall have not been recorded in Malaya. Thompson records the isolation of more than one "Phytophthoraceous" fungus from naturally occurring pod-rot, and it is also known that the fruits are very susceptible to infection in that country. When conducting artificial inoculations on the fruits of one tree in 1917, infection and spread took place so rapidly that, within ten days, three neighbouring trees showed every fructification more or less severely infected, and steps had to be taken to clear away at once all the diseased pods. This inoculation work on fruits was carried out by Belgrave.

The following abstract is taken from Petch's account of abnormal leaf-fall:

In Ceylon the South-West Monsoon is supposed to burst in the latter half of May, and June and July should be months of heavy rainfall. If the rains of May and June are fairly continuous a second fall of leaf may set in about the beginning of July, and if the rains continue through July and August this leaf-fall is continued also. But should dry weather intervene, the leaf-fall ceases. Trees rarely lose all their leaves, but they may lose the greater portion of them so that the ground is thickly covered with dead leaves.

This abnormal leaf-fall is known to occur in Ceylon, South India, Burma

and Java, It has been referred to as monsoon leaf-fall and second leaf-fall, but the term abnormal leaf-fall appears the most appropriate. In South India its incidence is similar to that in Ceylon, but a little later, in accordance with the later burst of the monsoon. According to McRae, the trees begin to shed their leaves about a fortnight after the monsoon has set in steadily, and the leaf-fall is most noticeable from the middle of July to the middle of August, by which time the trees cease to shed their leaves to any appreciable extent.

This disease is intimately associated with the fruit-rot, or pod disease, of *Hevea*. In all the countries in which abnormal leaf-fall occurs the cause of the principal abnormal leaf-fall is a *Phytophthora*, which in the general case, attacks the fruits first and then passes from them to the leaves and branches.

The fruit rot which occurs in Ceylon was determined to be due to a *Phytophthora* sp. in 1905. In that year it threatened to destroy the whole fruit crop, but it was not associated with any marked leaf-fall. An abnormal leaf-fall occurred in Ceylon in 1909, but in August, after the seed had ripened. In 1912, leaf-fall and pod disease occurred together, and it was then determined that leaf-fall was also due to a species of *Phytophthora*. *The dependence of the disease on climatic conditions during the time the fruits are ripening is very marked in Ceylon.*

Die-back of Shoots.—After a severe outbreak of leaf-fall and pod disease, many of the green shoots are found to have died back, and, according to observations in South India, this dying-back may proceed further, along the larger branches, during the ensuing cold weather. McRae has demonstrated that this die-back is also caused by a species of *Phytophthora*, and that the mycelium of the fungus is present in the dead and the living tissues of the branch. On splitting open a dead branch, a dark-brown line is found separating the living from the dead part. The mycelium may be found on either side of this line, not only in the brittle dead portion, but also in the tough living tissues. It occurs in the bark, wood and pith. In some cases it extends only an inch or two along the living part, while in others it is found much further along, especially when fresh young shoots have developed. It has been shown that the fungus invades the branch from the fruit-stalk or *via* the terminal bud. It can, however, attack the green shoot directly, and in the earlier stages of an attack of leaf-fall it is often possible to find blackened sunken areas on the green shoots, coincident with the appearance of the disease on the leaves and independent of diseased leaf-stalks.

The mycelium of the fungus lives through the dry weather in the branches which have partly died back. According to McRae, the new shoots which are produced from the living part of these branches in the following spring may begin to wilt about a month later. The leaflets shrivel, dry up, and fall off; the lowest inch or so of the shoot becomes discoloured: and the shoot ultimately dies back to its parent branch. In many such cases the mycelium is not in the leaves but in the branch, and it would appear that it is the effect of the fungus within the branch which causes the new shoot to shed its leaves.

It must be borne in mind that this form of die-back is only likely to occur during or after an attack of fruit disease and abnormal leaf-fall. There are many other causes of die-back of the green shoots of *Hevea*, and it is scarcely possible to distinguish between them without a microscopical examination of the dead twigs. Shade is responsible for the death of many branches, especially in the lower part of the tree, while there is reason to suppose that too frequent forking, more especially on poor soils, may have the same effect. Of diseases, *Gloeosporium alborubrum* and *Phyllosticta ramicola* may cause die-back of the green shoots, and several other fungi are under suspicion.

Preventive Measures against Abnormal Leaf-fall.—The paragraphs following contain some observations by the writer, but as abnormal leaf-fall caused by a species of *Phytophthora* has not been found in Malaya, it is considered the better procedure to continue this section in close type.

Petch states that the principal cause of the rapid spread of the disease is the development of the fungus on the fruits. Once the disease has begun, the fruits serve as the main centres of propagation of the fungus and of distribution of the spores. Therefore any method of preventing fruit formation or diminishing their numbers, would supply a check to the spread of the disease.

The difficulties attendant on spraying tall rubber trees are well appreciated by all plant pathologists working on rubber. But Ashplant, working in South India, demonstrated that spraying with Bordeaux Mixture could be considered to be a practical estate measure. Such a statement depends entirely on the market price of the commodity for its validity. The costs of spraying, reported by Ashplant, varied between eight to seventeen rupees per acre; rupees may be considered the equivalent of Straits dollars in this connection. It would be totally impossible to consider such a large expenditure over the last three or four years, when low rubber prices have dictated economies along every possible line.

Ashplant's methods do not demand the use of power sprayers. Strongly constructed hand sprayers, with a spraying rod of about twelve feet long are used from movable platforms. The spraying is done in April or May before the burst of the South-West Monsoon. The results reported by Ashplant were considered so good that some 4000 acres of from nine to twenty years, and 6000 acres of less mature rubber were sprayed in 1925.

Ashplant also records that the results of preliminary experiments in the control of secondary leaf-fall by the application to the soil of synthetic urea are regarded as exceptionally promising, the trees in the treated plots developing 25 to 60 per cent more foliage than unmanured individuals. Satisfactory results were also obtained in February 1926, by the application of sodium nitrate and ammonium sulphate at the rate of two and three pounds per tree to two blocks which had received the same substances at the rate of three and four pounds in December 1924. The trees in the manured blocks are calculated to bear 30 to 60 per cent more foliage than those in the untreated.

The costs of these operations for control of secondary leaf-fall appear high at the present time, more especially when compared with the costs of

sulphur dusting as carried out for *Oidium* control. Five rounds of dusting with sulphur at the rate of five pounds per acre cost only about two dollars per acre in Malaya in 1933, and now suitable dusting machines are available, the advisability of dusting with either Bordeaux or Sulphur powders, instead of with liquid mixtures, might be considered for control of abnormal leaf-fall caused by *Phytophthora*. The supply of clean water for the making of Bordeaux or Burgundy mixtures would be a difficult problem on most rubber estates in Malaya, which doubtless could be overcome in most cases, but only by a large increase in labour costs.

Comparing spraying operations with hand-spraying and power-spraying machines, Ashplant states: "The maximum height that can be reached with a fine spray operated from the ground is from thirty to forty feet, is not much greater with a power than with a hand sprayer. With both, climbing has to be resorted to in order to reach the tops of the trees. It is this necessity for climbing that limits the possible task and takes so much time and labour. Could means be devised whereby the tops of seventy to one hundred feet *Hevea* trees could be reached by a ground operated spray or rather a battery of sprays, the full resources of power sprays would be capable of utilisation. The greater speed and labour saving then made possible would alter the position entirely to the advantage of power sprayers."

R. H. Stoughton described the spraying apparatus found most useful in Ceylon and South India for control of leaf-fall caused by *Phytophthora*. The particular machine is known as the D.S.P. "HEADLAND" pump. This is a double-barrelled force pump, with a large inlet hose, with a strainer, a steel pressure chamber and two half-inch outlets with stop-cocks. The machine is sent out unmounted, but should be fixed to a small wooden platform with four projecting handles for carrying. Spares for the pump are supplied but may be usefully augmented. Two lengths of hose are required, each seventy-five to one hundred and twenty feet long. If more than this length is used, undue wear and many bursts and other troubles are probable. The only hose that has so far proved capable of standing up to the rough usage is the "Armada" hose. To the end of each length of hose is attached either a bamboo "lance" (a long bamboo with a screwed metal pipe within it) or a light fifteen-foot steel pipe; to the end of this is attached a nozzle. Many types of nozzle have been tried but the most successful are the "Mistifier Junior" and the "Jumbo" nozzle. A new type of combined lance and adjustable nozzle has been put on the market at the instigation of Mr. Ashplant. This is called the Drake and Fletcher "Armada" spray gun and Ashplant reports that exceedingly good results were obtained by its use. With this instrument the type of spray produced is varied by turning the stop-cock at the handle end.

The labour requirements for each machine is best apportioned as under. It will be interesting to compare this with the labour requirements for sulphur dusting as given in the *Oidium* section.

(1) Two coolies working the pump.

(2) One coolie stirring Bordeaux Mixture and relieving pumpers in rotation.

(3) Four coolies spraying.
(4) Two to six coolies carrying water and mixing the Bordeaux.

GLOEOSPORIUM ALBORUBRUM, Petch, AND GLOEOSPORIUM HEVEAE, Petch

These fungi and others are commonly found associated with mite attacks. In such attacks, the leaves become distorted as a result of asymmetrical growth, while complete defoliation of the young shoots may take place.

The spore-bearing layers or *acervuli* of *G. alborubrum* appear as a pinkish spore-mass above the leaf surface, and when several acervuli are aggregated together they can be easily seen by the naked eye, more especially on or in close proximity to the midrib or veins. The single spores, as seen under the microscope, are hyaline.

G. heveae has been recorded on rubber trees in Malaya on but few occasions and in each case they happened to be associated with lightning damage.

Petch, Brooks and Arens all record that *G. alborubrum* has been the responsible agent in causing a leaf-fall in Ceylon and Java. The writer has no definite experience to record in connection with these fungi, excepting on a single occasion where an intense leaf-fall over some hundreds of acres took place. The rubber had been planted some three or four years and *Gloeosporium alborubrum* became quite prominent on large numbers of trees. The estate was situated in a low-lying coastal area and, a short time previous to the fall of leaf, the drains had been lowered rather hurriedly from a depth of four feet to six feet. The writer is of the opinion that the lowering of the water-table, as a result of the increased depth of the drains, was of greater importance in causing leaf-fall in this particular case than the fungus attack.

Over the last three years, mites and *Gloeosporium* attacks have been quite common on the leaves of young bud-grafts during the heavy rain-falls of the months of April and May, and while in 1931 they were particularly noticeable, in 1932 and 1933 the number of attacks were comparatively few. While the associated insect and fungus attack is more common in badly drained land, yet attacks have been inspected where the drainage certainly could not be considered at fault.

For successful control, drainage must be undertaken where necessary. The attacked leaves should also be dusted with powdered sulphur; four applications at five-day intervals have proved suitable.

BIRD'S EYE SPOT

Caused by *Helminthosporium heveae*, Petch

This leaf affection is frequently found in nurseries and often on leaves of older trees growing under unfavourable conditions. The fungus first causes minute purple spots, which become white as they increase in size. The spots are generally circular with a narrow, purple-brown border and are very numerous on badly affected leaves, but the individual spots are never large, rarely exceeding 5 mm. in diameter.

Helminthosporium heveae was described by Petch, on *Hevea brasiliensis*, more than fifteen years ago. Bancroft, in 1911, stated that there was no record of its occurrence in the Federated Malay States. Butler, in 1918, says the disease occurs in Malaya, Ceylon, South India and Java. Both Petch and Butler state that the fungus is confined to young rubber trees. This is usually true in Sumatra, but in 1919 La Rue found it on old trees on numerous estates. In some cases the leaves were riddled with spots and the injury must have been very considerable. The disease does not cause defoliation of the affected trees and where defoliation occurs it is usually found to be due to a simultaneous attack of mites. The fungus attacks the leaves and occasionally the bark of young twigs. Infection occurs just as the young leaves unfold, and the old leaves, either falling or still hanging on the trees are probably the source of the infecting spores. The fungus is easily grown in culture but is slow in producing fruits. The Sumatran form agrees with Petch's description but the spores are rather smaller.

This is the only leaf-spot which can be considered to do material damage in Malaya, and badly damaged nurseries need treatment. Periodical dusting with sulphur has given satisfactory results and a small sulphur-dusting gun, which can be purchased for a few dollars, is quite efficient in dusting nursery plants. Dusting should be continued at five-day intervals until the new leaves appear free from the fungus spottings.

SHOT-HOLE LEAF DISEASE

This is referred to because, in Malaya, spottings caused by *Helminthosporium heveae* lose their white centres quite commonly, giving the appearance of "shot-hole" leaves. Petch reports that the spots resemble those caused by *H. heveae*, but that fungus is usually

larger and in the case of the *Helminthosporium* the centre does not as a rule drop out.

Various fungi have been found on these spots. The following are given by Petch: *Scolecotrichum heveae*, Vincens; *Fusarium heveae*, Vincens; *Aposphaeria ulei*, P. Henn; *Zygosporium paraense*, Vincens.

The first-named, viz. *S. heveae*, is considered by Vincens to be the principal agent in causing the disease.

Rim Blights

Rim blights are of common occurrence in Malaya, but usually only single trees are affected and the fungi found on the dead or diseased leaf-rims have never caused serious damage. The effect of these fungi is to produce a narrow, whitish or brownish zone, about 1 cm. wide, extending all round or partly round the leaf. Petch records three different fungi as causing rim blight, and states that, without microscopical examination it is difficult to observe which fungus is responsible. These three rim blights are caused by the following fungi; *Ascochyta heveae*, Petch; *Sphaerella heveae*, Petch; *Guignardia heveae*, Syd.

It is unnecessary to give details of the structural features of the fungi concerned. Of the above, *A. heveae* and *S. heveae* have been recorded in Malaya.

Leaf Spotting

Caused by *Cephaleuros mycoidea*, Karst.

This organism, which is an alga and not a fungus, causes a purplish spotting on rubber leaves but rarely any material damage. It is much better known in connection with diseases of other crops, for on them it causes serious losses. It is the cause of the well known "red-rust" on Tea and is very troublesome in clove cultivation. It is one of the few algae which is capable of causing a plant disease.

This parasite, named *Cephaleuros mycoidea*, Karst. (=*Mycoidea parasitica*, Cunningham), is seldom strongly developed on healthy rubber trees, and even on rubber growing under poor conditions it does not do conspicuous damage. It causes small, circular, purple spots on the actual leaf-tissue, but on the midrib and veins the spots may be more or less elongated. The fructifications of the alga are produced on the spots as minute, erect, yellow-looking hairs. Ridley describes them as fine, white hairs, topped with yellow, but when seen in mass, the yellow tips give the predominant colour. These hairs appear under the microscope as fine filaments, bearing at their

ends a number of short arms, usually from three to nine in number, nearly equal in length. At the end of each arm, which is abruptly decurved, is a yellow, rounded body, the zoosporangium. Zoospores are produced in the presence of sufficient supplies of moisture, in a manner similar to that seen in species of *Phytophthora* and they escape through a small hole when ripe and swim about by means of two cilia.

Recently, the fructification of this parasitic alga has been found growing vigorously on the extrafloral nectaries of the leaves of unthrifty rubber trees.

Petch reports that: [1]

Cunningham named the species of *Cephaleuros* on Tea and other plants examined by him *Mycoidea parasitica*. There is not much doubt that he included more than one species under that name. Subsequently Hariot referred the superficial species described by Cunningham to *Cephaleuros virescens*, Kunze, a species collected in Cuba, and described in 1829. There is no type specimen of the latter, and the description is inadequate; consequently, Karsten (1891), in his paper on the *Chroolepidae* of Java, rejected Kunze's name and adopted the name *Cephaleuros mycoidea*. As Karsten's determinations are the first which can be definitely interpreted, they are followed here.

Sooty Moulds

Occasionally rubber leaves are found with a dense black covering, generally on the upper surface, the under surface remaining green. The black incrustation is caused by a fungus which belongs to a class usually known as Sooty Moulds (*Capnodiae*).

These fungi are not parasitic, and any damage done is indirect in so far as the black incrustation prevents the leaf from functioning properly by cutting off part of the light which would reach it under normal conditions.

The sooty moulds live on the sugary secretion of scale insects which are present on the leaves, and are especially plentiful along the veins. As the moulds cause no damage no treatment is necessary. The black incrustation usually disappears with the advent of rains.

Diseases of Green Twigs

In relation to diseases of green twigs and leaves, both Brooks and Petch refer to the action of *Gloeosporium alborubrum* and *Phyllosticta ramicola*. The latter fungus has been reported in Malaya on numerous occasions as occurring on leaves, and quite large patches of

[1] Petch, T., 1923. *Diseases of the Tea Bush*. Macmillan and Co., Ltd.

leaf tissue turn brown and die from the edge of the leaf, inwards. Both the above authors refer to the fact that the chief danger lies in the fact that shoots killed by these fungi may afford a point of entrance for the parasite causing die-back, i.e. *Diplodia* sp. But as pointed out in another section, it is extremely doubtful if the "die-back" fungus does function as has been thought in the past, at least as far as Malaya is concerned. The close association of the *Diplodia* die-back fungus with lightning damage is only just beginning to be realised, and descriptions given for attacks by *G. alborubrum* and *P. ramicola* on green twigs are applicable in every detail to trees affected slightly by lightning. The writer, since taking up the problem of lightning damage on rubber trees, has not had time to work on this particular phase of the more general problem, but all previous writers, in considering the question of *Diplodia* die-back, remark on the trees being killed in groups, only a few individuals of which are seriously affected. In general the descriptions tally, even to details, with lightning damage. The slightly affected trees in a group struck by lightning show many different symptoms, but one of the most common effects is a blackening of the green stem six to eight inches below the apex of the shoot. This is a symptom characteristic of *P. ramicola*, as will be seen in the description by Richards and others, given later. Recently an examination of specimens obtained from the slightly affected trees in a lightning group was made, and *Gloeosporium heveae* was present in abundance. Corner, working in Singapore, has had a similar experience. The writer cannot escape the feeling that the *P. ramicola–G. alborubrum* complex of past years is, in some fashion, connected with lightning injury. It is true that *G. alborubrum* plus mites can severely retard the growth of newly developing leaves of young trees but there is not much definite evidence to go beyond this. As the matter is still non-proven, it will be of advantage to give another investigator's account of the position.

Phyllosticta ramicola and Gloeosporium alborubrum

The following description was given by R. M. Richards, in 1917, when working as mycologist to the Malayan Planter's Association:

For the purpose of this paper these two fungi may be dealt with together as they are frequently intimately mixed on the same affected branch or twig. The two fungi are parasitic and usually affect the uppermost twigs which still have a green epidermis or skin—that is, where cork has not yet been formed.

Phyllosticta generally makes its attack at a point six to eight inches below the apex of the shoot. When first noticed a brown patch may be observed which later spreads upwards and downwards, killing the twig. Usually the fungus spreads no further down than two to three feet below the apex. *Gloeosporium* has a similar mode of attack. It is usually immediately after wintering when the leaves are just unfolding that the attacks of these fungi occur most commonly. I have seen several thousand trees affected on one estate within a few weeks. *Gloeosporium* is frequently the cause of the fall of the young leaves before they are fully developed—an effect of not uncommon occurrence.

As far as these two fungi are alone concerned the attacks are not dangerous. Dead twigs killed by the fungi are often found but the disease spreads no further. The real danger lies in the fact that their attacks afford opportunity for the entrance of *Botryodiplodia* and for this reason affected branches should be removed and all diseased portions burned.

More often than not, especially in flat lands, *Botryodiplodia* makes its entrance after the attacks of these fungi and, therefore, it is necessary that the utmost precautions should be taken to prevent a serious local epidemic of die-back.

Since the above was written, a case with similar symptoms to those described by Richards has been noted. They became prominent on a group of about eighteen one-year-old, unbranched, budded plants. The earliest stages showed a brown patch of tissue appearing on the stem below the apex and in proximity to the second storey of leaves; in the majority of cases not more than four to six inches of stem tissue were involved. Spore development had not occurred on the discoloured areas, but a species of *Gloeosporium* and *Phyllosticta ramicola* were isolated from the diseased cortical tissue; there was no discoloration of tissues internal to the cortex. There was a discoloured brown patch of stem just above the second storey of leaves, the place being indicated by leaf stalks, the leaflets having fallen off. When looked at closely, it could be seen that some of the leaves in the topmost storey were torn and possessed shrivelled, discoloured tips. A later stage showed the discoloration of the stem tissues progressing upwards to reach the tip of the stem; the upper storey of leaves and leaf stalks have fallen completely, and new, leafy side branches were springing out from the axils of the leaves of the second storey of leaves and also from the stem region in close proximity.

The primary seat of infection is the discoloured area of stem situated just above the second storey of leaves. There is little downward progress to be noticed, but vertical progress is rapid, and the whole of the stem, up to the extreme tip, becomes involved.

These specimens were brought in from the Experiment Station of

the Rubber-Research Institute on October 14th, 1933. Enquiries through the Manager elicited the information that heavy lightning storms occurred in the near vicinity on September 11th, 1933, and September 28th, 1933, the earlier one being the most severe. This particular case, while not providing incontestable evidence, supports the writer's views regarding the effects of *Gloeosporium* sp. and *Phyllosticta ramicola* in providing places of entry for the *Diplodia* die-back. Details of lightning effects will be given in the chapter following.

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SECTION 5

SCORCHING AND AFTER-EFFECTS, AND MISCELLANEOUS

CHAPTER XVI

SCORCHING AND AFTER-EFFECTS

Lightning Damage—Leaf Fires—Sun-scorch of Exposed Lateral Roots—Death of Seedling Plants caused by Excessive Ground Heat—Die-back of Snags and Spear-head Wounds at Junction of Stock and Scion.

INTRODUCTION

THE close connection between scorching effects and the *Diplodia* species causing die-back in rubber trees has been referred to, and a list of affections is given on page 279 in which this fungus shows up prominently. In the headings to the present chapter the items included in the list are repeated, with one addition, viz. leaf fires, where the prominent fungus up to date has proved to be *Ustulina zonata*. A résumé of the inoculation experiments which go to prove that the *Diplodia* die-back fungus will only penetrate readily into the tissues of *H. brasiliensis* under special conditions when local areas of cortical tissue are scorched, is given in the section headed Sun-scorch of Exposed Lateral Roots.

Lightning and leaf fires produce direct damage which is easily observable. The remaining four items listed, required very careful attention before substantial evidence was obtained which offered a rational explanation.

LIGHTNING DAMAGE

For many years the writer has been in close touch with the problem presented by lightning damage in coconut plantations, and has stated his conclusion that lightning plays an extremely important role as the initiating cause of diseases of coconut palms in Malaya. As a result of the experience gained while investigating coconut diseases, careful attention has been directed towards estimating the amount of damage done by lightning in rubber plantations. Lightning damage has been noticed in rubber plantations in Malaya for many years

past, but the year 1933 was outstanding in showing the serious damage which may accrue from this cause. Furthermore, the observations made during 1933 showed that the special features met with in coconut plantations are duplicated in rubber plantations, viz. numerous small patches of trees affected by lightning are frequently reported, and very occasionally large patches of trees, damaged in exactly the same fashion, are found.

Weir summarises the general position as follows:

> The pernicious tendency of lightning to cause damage to plants has been well shown in rubber. Many cases have been investigated and talks with planters demonstrate the common occurrence of lightning injury to young rubber. The "die-back" of 4-12 months old trees wherein the tops wilt, the green bark turns black with the appearance later of three or four caulicolous fungi, finally resulting in death, is apparently attributable to lightning. The affected trees occur in patches and when cut back to stump height regenerate rapidly with a discontinuance of damage.
>
> The influence of lightning on the growth of trees, if the trees are not killed outright, usually takes the form of a modification of the developing wood cells of the season, so that the continuity of the normal structure of wood is broken and a "lightning ring" is formed.

Most of the information detailed here is extracted from an article by the writer published in the *Annals of Applied Biology* in 1933.

The observations on the effects of lightning on rubber trees can be most conveniently treated under two headings:

(*a*) Lightning effects and die-back, usually found on young trees.

(*b*) Lightning effects and claret-coloured bark canker at the collar, found on trees from four to twenty years of age.

(*a*) The symptoms shown by young rubber trees affected by lightning are well described in the quotation from Weir given above. The affected patches usually contain from eight to twenty trees, (Fig. 49), a few of which will be severely affected so that death supervenes quickly; the remainder will be slightly affected only and can be saved by pruning back to healthy wood. The important point is that few total losses occur, for young trees are seldom killed outright and in those cut back to stump height, the cut being made through unaffected healthy tissues, regeneration is rapid, growth in length being continued by the shooting of lateral buds from unaffected tissues. A careful examination of the root systems of young trees affected by lightning is necessary to make certain that the symptoms shown are not the result of an attack of one of the fungi causing root disease, but only a single case, here and there, need be opened up. In fact, the various features are now so well established

that, except in very exceptional circumstances, a root examination can be dispensed with.

The following is a record from an area recently affected by lightning. The area was planted in 1928 and bud-grafted in December–January 1929–30. There were two areas affected: a large area situated on an exposed hilltop and a small area on the side of a hill, one mile distant.

The lightning storm, which occurred on November 3rd, 1931,

FIG. 49.—Photograph showing usual appearance of the individual trees in a group struck by lightning. Note leafless stem tops in trees affected.

was a notably severe one. Nothing unusual was seen on the plantation until November 11th, 1931, when over 100 trees were found showing the symptoms described above. The writer was notified on the date last mentioned and an inspection of the affected area was made on November 13th, 1931; on this visit a careful root examination was undertaken, and this showed the root systems to be perfectly healthy. In the larger area, 121 trees were treated; of this number, eight had to be cut out completely, the rest were treated successfully by pollarding. The number of treated trees in the smaller area was twenty, of which five were total losses. It should be noted in this case, that the date of the storm was November 3rd, and the first indication of

damage was seen on November 11th, eight days afterwards. The period elapsing between date of storm and signs of lightning damage appearing on the trees varies between eight to fourteen days.

A further unpublished record of a large area affected by lightning was made in 1933, in which 215 bud-grafted trees, two to three years of age, showed definite signs of damage. A plan is given (Diagram No. VIII). Two centres of affection show up in the plan, the first diffuse, with an ill-defined centre, lying between vertical rows 8 and 20 and horizontal rows 7 and 17. The second is concentrated between vertical rows 15 and 26 and horizontal rows 25 and 33. In connection with this attack, the following paragraph was written in the official reply making recommendations:

> It is possible that the area affected will not spread to any great extent beyond the limits shown in the plan. In order to obtain a more precise conception of the manner in which the affection may spread, it will be advisable to make a second plan at the end of this week and a third at the end of next. Between the second and third inspections the rate of increase should be practically nil. If it shows signs of rising, then the lightning theory will have to be discarded. No treatment beyond pollarding is possible.

In reply to this letter the manager reported that on the third examination no new infections could be discovered. In the majority of cases where a length of one to two feet of the scion was not affected by lightning or its after-effects, the buds were shooting with great vigour and the total losses numbered only twenty-eight.

R. M. Richards described an outbreak of *Diplodia* die-back, in 1917, in these words:

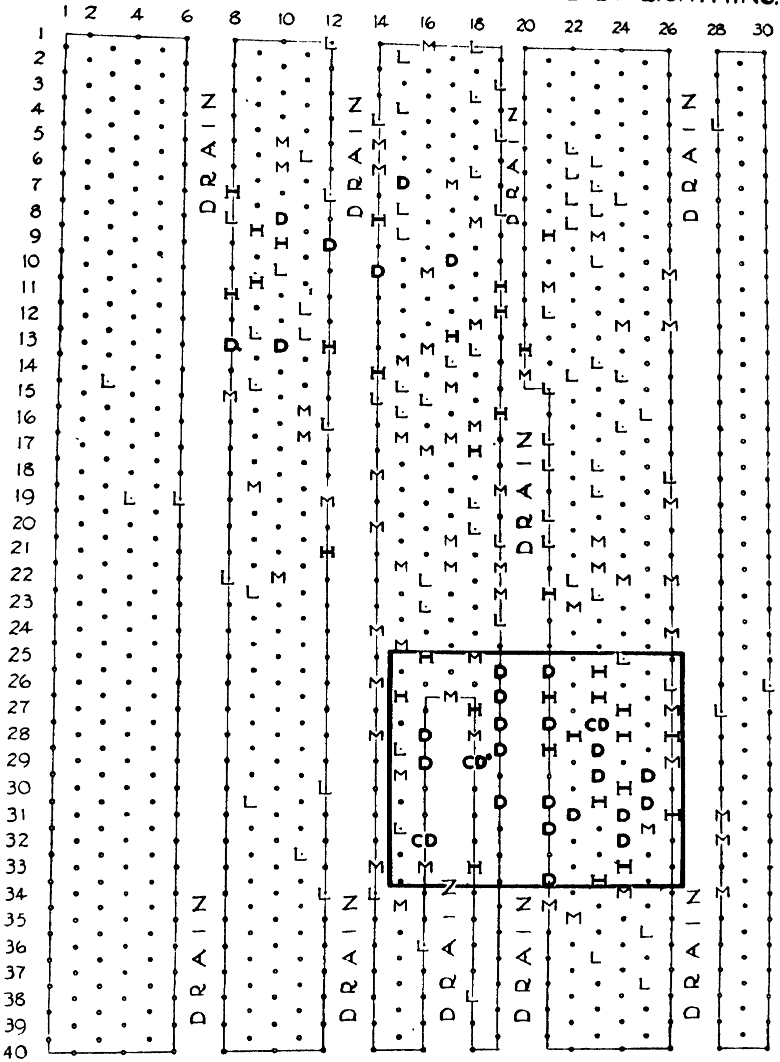
> On one estate I recall an occasion on which 150 trees seven years old were found affected in one group. A few of these trees, not more than six, were killed but many of the others had to be cut below the fork. Usually one tree is found killed and a group of trees in the immediate vicinity more or less seriously affected.

The above seems an accurate description of a typical lightning strike.

At this stage it may be of interest to give the gist of the general theory proposed by Dr. G. C. Simpson, which has a definite bearing on lightning in rubber and coconut plantations in Malaya. He distinguishes three types of electrical discharge, only two of which need concern us here, viz.:

The discharge to the ground from a positive cloud.
The discharge to the ground from a negative cloud.

DIAGRAM OF TREES ON G ESTATE AFFECTED BY LIGHTNING.



L	LIGHTLY AFFECTED	80
M	MODERATELY AFFECTED	63.
H	HEAVILY AFFECTED	34.
D	SCION KILLED BACK TO UNION	26
CD	BOTH SCION AND STOCK KILLED	2
CD*	SEE SPECIAL NOTE IN TEXT	1

Diagram VIII

The characteristics of the two types of discharge to the ground are very different. The discharge from a positive cloud starts high up in the atmosphere and branches out on its way to the earth. An earth-connected object may therefore be struck either by the main "trunk" or by one of its branches. On the other hand, a discharge from a negative cloud starts on an earth-connected object which takes the whole discharge. Thus the chances of being struck are much greater with a positive discharge than with a negative discharge.

The theory leads to the conclusion that discharges from positively charged clouds would be frequent but weak, while discharges from negatively charged clouds would be infrequent but very strong. In both coconut and rubber plantations the feature of numerous slight discharges affecting six to twenty trees, and occasional heavier discharges affecting one hundred to three hundred plants is quite obvious. This year (1933), over thirty reports of lightning damage on rubber plantations have been received but the only serious case was the one illustrated by Diagram VIII.

With reference to the prevalence of lightning in different countries, it is stated[1] that Java is the most intense spot in the world and apparently has more than twice as much lightning as any other part of the world. The close proximity of Malaya to Java is worthy of note.

(*b*) Rubber trees, from four to twenty years of age or over, have been found affected by lightning discharges and they showed the unexpected feature of typical symptoms of claret-coloured bark canker, i.e. patch canker, developing in the region of the collar, at ground-level. The fungus, *Pythium complectens*, Braun, was isolated in every case and proved to be the active agent rotting the cortical tissues at the collar.

The first case of lightning injury on trees four to five years of age was investigated in March 1931. The trees were planted on a hilly slope, on contours, and the ground was covered by a thick growth of the cover crop, *Centrosema pubescens*.

A lightning storm was noted in close proximity, five days before the affected trees were found. Trees on two contours were affected; on the lower contour two dead trees only were found, but on the upper, one dead tree and, in addition, seventeen neighbouring trees, all slightly affected at soil-level, were observed.

The dead trees were taken out immediately. The seventeen trees, presumably affected by lightning, showed discoloured cortical tissues at ground-level. This discoloured tissue formed a patch about six

[1] Shipley, John F., 1933. "Lightning", in *Distribution of Electricity*, June, p. 1276.

inches square and extended through the entire thickness of the cortex. The discoloured patches showed symptoms exactly similar to those described for the panel disease of *Hevea*, known as patch canker, and from them *Pythium complectens* was easily isolated.

The important point in these findings was that if the trees showing the bark attack at the collar had remained unnoticed at the time the dead trees were taken out, and had been left untreated, there would have been a peculiar outbreak of root disease reported a few months later, for which it would have proved difficult to provide the correct explanation.

The cases of claret-coloured bark canker recently found in Malaya associated with trees affected by lightning are invariably those in which the tree is attacked at the collar. The chief danger in such cases is that boring beetles, which are attracted by the smell of the affected tissues, may enter the tree and, if this happens, such trees succumb, in the majority of cases.

With reference to the identity of the fungus causing the symptoms, the position was somewhat confused owing to the existence of several species of *Pythium* and *Phytophthora* which are known to be capable of producing disease symptoms in *Hevea brasiliensis*. Thompson has showed that two species of *Phytophthora* and one species of *Pythium* are direct causes of patch canker in Malaya; further, that seven other species of *Phytophthora*, isolated from host plants other than *Hevea*, are capable of causing patch canker symptoms if artificially inoculated into the bark of rubber trees. Thus it seems obvious that more than one species of *Pythium* or *Phytophthora* may be involved in the production of the diseased cortical tissues which are found at the collar of mature trees affected by lightning. However, the later work which led to the identification of *Pythium complectens*, as being the commonest cause of patch canker in Malaya, supports that of Thompson's.

The most noteworthy occurrence of the association of lightning and claret-coloured bark canker at the collar can now be described. During the investigations on lightning effects the writer has noted the dates of lightning storms occurring in the vicinity of Kuala Lumpur. Two heavy thunderstorms were noted on November 18th and 19th, 1931; both took place between the hours of 1.30 and 4.30 P.M. On December 2nd, 1931, a report of lightning damage was received from an estate only three miles from the Rubber Research Institute. A visit was made and several lightning patches were found on trees twenty years of age. There was no cover-crop present.

The affected patches were situated on a direct north-and-south line. The total number of trees found affected was 56. Of these, 8 were killed outright and 48 were treated for claret-coloured bark canker or patch canker, at the collar.

The symptoms shown by the affected trees could not be mistaken. The badly affected trees which had to be cut out were killed as a result of the scorched cortical tissues being rapidly invaded, both by boring beetles and the *Diplodia* fungus which causes die-back in rubber trees. This black, discoloured cortical tissue proves attractive to boring beetles, and the rapid penetration of these insects results in the quick death of the tree. The borer attack on badly affected trees is of importance when considering treatment of the slightly affected trees, showing typical symptoms of claret-coloured bark canker at the collar. Because patch canker tissues attract boring beetles, it is imperative to remove as quickly as possible not only the trees which must inevitably succumb, but also the affected tissue at the base of slightly affected trees to prevent penetration of the latter by these insects.

The slightly affected trees all showed the typical symptoms of patch canker at ground-level in greater or lesser degree. Figs. 35 *a* and *b* show the appearance of an area of discoloured cortical tissue, ten inches by five inches, which was stripped from the wood at the collar of one tree. Fig. 35 *a* shows the extent of the discoloration of the affected area when the outer bark layers are scraped away. Fig. 35 *b* shows the appearance of the inner surface of the affected cortical tissues; this surface is directly in contact with the wood, and a reflection of this appearance is found on the wood surface. The white patches are pads of rubber caused by coagulation of latex which has infiltrated from the attacked cortical tissues; in some way a cavity is formed by separation of wood and cortex at the cambial layer and the latex finds its way into this, finally becoming coagulated.

The photographs illustrate an extreme case in which a comparatively large bark area is affected, with the fungus penetrating to a slight depth into the wood beneath. The more numerous cases are those in which a smaller patch of cortical tissue is involved, and though the wood surface beneath is discoloured, there is no penetration of the woody tissues by the fungus.

The treatment of the trees showing the small patches of diseased tissue at the collar is as recommended for patch canker.

Steinmann reports that Rutgers and La Rue mention a cherry-coloured or purple discoloration of bark and cambium in cases of lightning wounds. According to these authorities this discoloration

remains visible for a short time and can only be seen in trees discovered quickly.

Rutgers has investigated the effect of lightning on *Hevea* in Sumatra, where injury due to this cause is by no means rare in some districts. He classifies the effects under four headings:

(1) Single trees or groups of trees may be killed. In some instances one tree is killed, while the branches of the trees nearest to it are withered. In other cases, one or more trees are killed, and the tops of the neighbouring trees wither *as in die-back*. The bark may be killed in a longitudinal strip, sometimes running spirally down the stem, and the dead strip is soon attacked by borers.

(2) Trees which have been struck by lightning but not killed may bear short, vertical wounds on the stem, sometimes arranged in a spiral line. These may be accompanied by *wounds at the collar*.

(3) The exudation of latex from the upper branches is regarded as another form of injury caused by lightning.

(4) The fourth type of injury is the scaling-off of the outer layers of the bark on the upper branches apparently somewhat similar to that known as "Top-canker" in Ceylon.

The mention of die-back in (1) and of wounds at the collar in (2) is of some significance in relation to the observations made in Malaya.

La Rue's description of lightning injury to *H. brasiliensis* is also interesting in view of the observations made in Malaya, and there seems little doubt that his observations, made in Sumatra, parallel those described herein. La Rue states:

The purple colour developed in the cambium which has been killed by lightning has already been sufficiently emphasised. This is of value in diagnosing lightning injury in *Hevea* trees as it is very rarely developed in cambium killed by other agents. *This colour often extends outwards into the bark nearly to the cork.*

After the bark is dead it is markedly different from bark killed in other ways. The bark of *Hevea* is always full of stone cells, and in bark killed by lightning all the other cells disintegrate within a remarkably short time leaving nothing but the stone cells with the strands of rubber which have coagulated in the latex vessels. The nature of the bark is a sufficient indication of lightning injury in cases where it is too late to detect the characteristic discoloration.

Without doubt a great many cases of die-back in the tops of *Hevea* trees are due to lightning but are erroneously attributed to *Diplodia* or some other organism.

Rutgers states he has never seen branches or strips of wood and bark torn from *Hevea* trees injured by lightning. The writer (La Rue) has observed three cases of this type of injury, but it is extremely rare.

The spread of the discoloration in the cambium and bark is curious and

closely resembles the progress of an infection. It appears that the path of the lightning is not on the surface of the tree as it usually appears to be in injuries to trees in Europe and America, but through the cambium. This tissue seems to offer the best path for the conduction of electricity. However, it may be that the current passes mainly through the water in the vessels of the sap-wood and that the wood does not readily show the injury. The cambium which lies nearer the sap-wood than does the phloem or cortex shows evidence of derangement earlier than either.

There is no doubt that lightning injury takes many peculiar forms. One of the features mentioned in the extract from La Rue's paper, where a large area of cortical tissue is stripped clean away from the wood and no other sign of injury is apparent, was noted in 1933. The area of bark affected was situated 1½-2 feet above ground-level; at the lowest level the split between cortex and wood was complete and the cortical layers were lifted wholly from the wood for a distance of about twelve inches. In this case, only two trees were affected.

During the year 1932, numerous cases of lightning damage plus claret-coloured bark canker at the collar were reported. During 1933, up to September, no cases of this particular affection have been reported although lightning injury plus *Diplodia* die-back has been extremely common on young plantations.

Another point of general interest which has already been mentioned is that the clone B.D.5 appears to be very susceptible to lightning damage in the first two years. The reason for this is probably the habit of growth. Trees of this clone show very rapid growth in height with a late branching habit, so that tall, non-branched stems are produced which apparently attract lightning. At any rate it is found that young trees belonging to the particular clone, when grown in blocks contiguous with those of different clones, are always the ones to suffer most severely from lightning damage. This feature is shown in Diagram No. IX, in which a plan of the trees affected by a lightning strike is given; the area affected is carrying an intermixture of different clones, and while B.D.5 is more severely affected than the remainder in this case, it is run close in this respect by the trees of A.V.R.O.S.256.

In conclusion, it may be of interest to place on record the writer's experience in 1933. It seemed probable that if lightning was an extensive source of damage in rubber plantations, substantial evidence should be forthcoming if the dates of the severe lightning storms occurring in the vicinity of Kuala Lumpur were tabulated and compared with those of lightning damage reports received from plantations. When dealt with in this systematic fashion, all doubts regard-

ing the injurious influence of lightning storms on rubber plantations quickly vanished. In nearly 80 per cent of storms recorded, reports

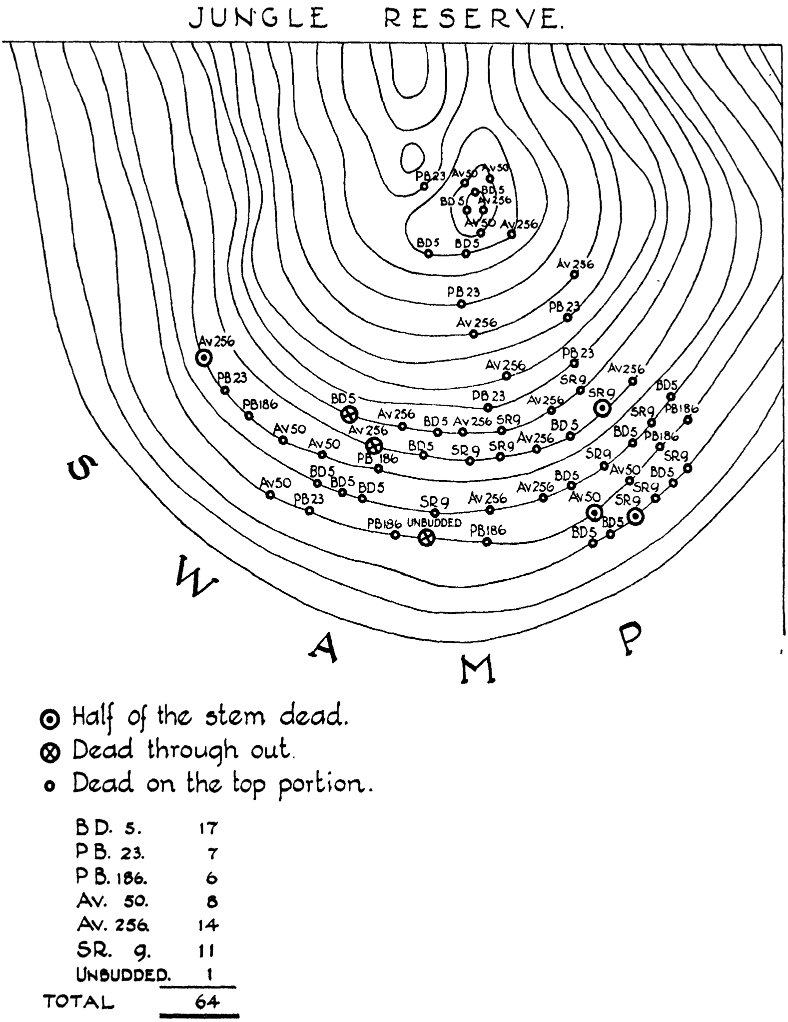


DIAGRAM IX

of damage to rubber trees were received from estates situated within fifteen miles of Kuala Lumpur, always within a period of ten to fourteen days.

LEAF FIRES

During normal years when wintering is a more or less gradual affair, leaf fires are seldom numerous. There may be a localised district from which an occasional report may come, where a period of drought has brought about a heavy fall of leaves; in general, the wintering carries on during February into March, some trees being leafless, some have regained their new flush of leaves and some, estimated to be about 15 per cent, do not winter at all in the early season, but carry over till the later dry period about August, when there is a second, subsidiary wintering.

During a season such as the wintering period of 1914–15, which proved to be a very regular one (i.e. more concentrated in time), the whole of the trees on many Malayan estates were quite devoid of leaves over short periods. A thick layer of dry leaves formed on the ground and such a carpet is very inflammable. Estates lying alongside the railway are very prone to leaf fires because the sparks from passing engines are quite capable of igniting the carpet of dry leaves. Once started, the fire passes over large areas with amazing rapidity, scorching the trunks up to a height of ten feet. Usually the passage of the flames is so rapid that only the surface of the tree is scorched, and occasionally the burning of the deeper cortical tissues is avoided.

If left untreated, boring beetles may be at work three days after the fire is extinguished. If immediate steps are not taken the insects multiply rapidly, and a large number of trees may be lost. Several estates lost four to eight acres of mature rubber in 1914–15 owing to neglect of treatment of the scorched trees after the leaf fires had been extinguished.

The prominent fungus in cases of trees scorched by leaf fires proved to be *Ustulina zonata*, not the *Diplodia* die-back fungus, though the latter was present. *U. zonata* is commonly found associated with attacks by boring beetles, and if neglected cases of trees scorched by a leaf fire are found heavily attacked by boring beetles, the wood will usually show the typical symptoms.

Treatment of Trees scorched by Leaf Fires.—For the purpose of treatment, trees scorched by leaf fires can be divided into two groups: (*a*) badly scorched, (*b*) slightly scorched.

Treatment should commence as soon as the coolies can work in the burnt areas. All possible labour and supervision should be concentrated on treating the lightly scorched trees rapidly; if the insects get well into the wood there is little hope of saving the trees.

The trees which show only the outer cortical tissues damaged by fire are those falling in the group (*b*). If treatment is carried out promptly all the trees in this group should fully recover. The treatment recommended is that all the scorched cortical tissue should be scraped away with an instrument such as a piece of hoop iron, until healthy tissues are exposed; the exposed surface should then be painted with a mixture of 80 per cent tar and 20 per cent crude oil. As a further measure of precaution a second painting might be given seven to ten days after the first.

With reference to group (*a*), the cortical tissues may be so badly burnt that treatment involves the removal of the whole of the bark. Usually, in these cases, one side of the tree is more badly burnt than the other and the cortex on the more lightly scorched side may be saved by treatment as recommended for group (*b*). During prosperous times it might be well worth while to treat such trees, but at the present time it would probably be more economical to cut badly burnt trees right out. However, if badly burnt trees seem capable of proving amenable to treatment, and if it is proposed to let badly burnt trees remain, the following operations should be undertaken. The whole of the burnt tissue should be cut away and the exposed wood surfaces coated with the mixture of tar and crude oil in the proportions given above. A second coating should follow the first after a few days' interval and the trees should be inspected regularly, an extra coat being given as long as there are still signs of the beetle attack.

Copious exudations of latex usually take place from bark tissues which have suffered severe burning.

Sun-scorch of Exposed Lateral Roots

In 1926 a lengthy dry period was experienced at the usual wintering time, February–March, and, as a consequence, the plantations in Malaya were practically leafless for a comparatively long period. As the usual wintering period in Malaya is somewhat uneven, there is usually fair amount of shade in the plantations.

All the trees were leafless at the same time during the wintering period on estates in the vicinity of Kuala Lumpur, in 1926, and the daily temperatures were particularly high during the period.

While the trees were leafless, attention was directed to an affection of exposed lateral roots, the symptoms of which suggested those of lightning damage or scorching. The disease or affection was first noted on a hilly estate and the lateral roots were well exposed,

probably due to loss of top-soil by erosion. On these exposed roots slight cracks appeared in the bark, which, on further examination, showed a much greater extension of apparently scorched, dead, dry tissue than the external cracks would indicate. Wounds, often two feet long, had to be made to clear away the dead woody tissue when the external cracks were not more than a few inches long. The affected woody tissue beneath the dead bark showed the typical greyish discoloration caused by the intrusion of the *Diplodia* die-back fungus. The wood was not penetrated to a depth of more than one inch, but was affected to a far greater extent than the limits of the dead bark.

The fungus was making progress slowly through the wood but apparently making none, or very little, through the cortical tissues. A yellow discoloration was often to be seen on the inner boundary of the discoloured wood.

No records of a similar outbreak could be found by the writer and the matter was somewhat disturbing for the following reasons. The percentage infection was about 10, a rather high figure. When trees are damaged by lightning, the progress of the die-back fungus is often very rapid, and death may ensue very quickly; further, there was no obvious explanation, for the fungus, when isolated in pure culture, proved to be the usual *Diplodia* die-back fungus. When this fungus was inoculated in fairly large quantities into wounded and unwounded roots, the results were negative. Similar results were obtained using large portions of diseased woody tissue as the inoculum.

These negative inoculation results led to the conclusion that, except under exceptional circumstances, the disease was not likely to spread rapidly, and thus should escape boring beetles. Fortunately no indications of the presence of boring beetles were observed throughout the whole period.

The problem of the apparent scorching was not easily solved. No fires had been reported; the position of the wounds and distribution of the diseased trees precluded the explanation of lightning damage. After a careful study of the whole list of possible contributory causes, the evidence obtained supported the explanation of "Sun-scorch".

The distribution of the affected trees on the hilly slopes was such that moving east to west round the hill, no affected trees were found on the east side; then as the west side of the hill is approached, a few mild cases were found, while when the west side is finally reached, several trees in the same row were found severely affected. The same sequence is met with moving over the top of the hill from east to

west, no cases on the east, a few isolated cases on the top, then a heavy infection on the west side. Further, on individual trees, showing a ring of exposed lateral roots, those shaded by the trunk on the eastern side were unaffected or only slightly affected. Thus it appears fairly conclusive that the exposed lateral roots on the western slope were scorched because they encountered the full force of the direct rays of the hot afternoon sun, during a period when the trees were leafless and shade was absent. The scorched bark areas were next invaded by the *Diplodia* die-back fungus, which rots the bark to a comparatively small extent and penetrates slowly in the wood.

Later, Ward obtained substantial evidence by means of inoculation experiments, which supports the explanation of sun-scorch as the cause. These inoculation experiments also strongly suggested that the *Diplodia* die-back fungus is not an ordinary wound parasite under normal conditions, but that it is a special type of wound parasite which can only gain entry into vigorous tissues with the greatest difficulty, but if a localised area of cortical tissue is killed by overheating, a strong infection follows and the fungus can then make rapid headway in the woody tissues of *H. brasiliensis*.

This feature is of special importance in so far as several different affections of *H. brasiliensis*, in which the *Diplodia* die-back fungus figures prominently, can all be shown to be initiated originally by overheating of cortical tissues. A résumé of Ward's inoculation experiments is given below:

Expt. 1.—It is necessary first to know whether the fungus found in roots affected by sun-scorch is capable of directly infecting healthy root-tissue, and whether it will function ordinarily as a wound parasite.

Six wounds on six individual lateral roots were made; areas about four inches long and one inch wide were cut into the woody tissue of the roots. Coagulated latex produced at these wounded points was removed the following day and six pieces of fresh sun-scorched tissue, containing the fungus, of slightly less size than the wounds, were then placed on the wounds. Inoculations were wrapped in cotton-wool to prevent contamination as far as possible. After fourteen days, the results were negative; they were still negative after five weeks.

Expt. 2.—Effects of scorching on inoculated and uninoculated lateral roots. Twelve leaf fires were made on twelve lateral roots. Six roots were inoculated with small pieces of sun-scorched tissue, and six were not inoculated, but left merely scorched, The roots scorched and inoculated showed five out of six successfully inoculated, the tissues becoming well impregnated with the typical discoloration. The roots, which were scorched only, showed early symptoms of sun-scorch; the characteristic symptoms had only just penetrated slightly into the woody tissues. In no case did the discoloration proceed so far as in the roots scorched and inoculated,

although two cases, more advanced than the remaining four, were noticeable.

Expt. 3.—Eighteen roots were scorched by leaf fires and inoculated as follows:

(*a*) Inoculated with the fungus grown in pure culture.

(*b*) Inoculated with fresh sun-scorch tissue from diseased lateral roots.

(*c*) Roots scorched but not inoculated.

Three weeks later, all the specimens treated as in (*a*) and (*b*) showed the typical wood discoloration of sun-scorched tissue; in (*c*) the fungus had penetrated through the scorched tissue but had passed into the wood only to a very small extent as in Expt. 2. Two of the controls showed the fungus entering the cortical tissues well outside the scorched area.

These inoculation results with both infected pieces of tissue and the fungus from pure cultures are quite positive and indicate the important part played in the successful infection of the cortical tissue of *H. brasiliensis* by scorching. If scorching is not carried out, the results obtained are seldom positive even after a long period of time has elapsed.

Further inoculation experiments were made to determine the amount or severity of scorching required for successful penetration of the fungus. The results were not clear-cut, but again the die-back fungus successfully penetrated through cortex scorched for thirty seconds with an iron bar. A few inoculations were made on branches, scorched in a similar manner for thirty seconds, with the addition of material from pure cultures of the *Diplodia* die-back fungus. After three weeks the fungus had penetrated well into the wood while the results obtained by inoculating branches with pure culture material without previous scorching were very different; in such cases the fungus had not penetrated into the wood after more than a six-weeks period.

While the experiments quoted cannot be regarded as providing final proof, they offer strong indications of the main predisposing factor which favourably influences, and enables the *Diplodia* die-back fungus to make a successful entry into the tissues of *H. brasiliensis*. This evidence, coupled with the prominence of the fungus in such affections as lightning injury, sun-scorch of lateral roots, die-back of seedlings owing to excessive ground heat, die-back of snags and the development of spear-head wounds at the junction of stock and scion, affords strong justification for proposing that all these troubles are initiated by the overheating of plant tissues in localised places.

The treatment of lateral roots affected by sun-scorch is quite simple; all that is required is complete excision of the affected parts, the cuts

being made well behind the discoloured wood tissue; the diseased parts cut out should be destroyed by fire.

Death of Seedling Plants caused by Excessive Ground Heat

It has been reported, both from Java and Ceylon, that seedling rubber plants have been killed or damaged by excessive ground heat. Two cases have been observed in Malaya which might be attributed to a similar cause. In both cases, however, the *Diplodia* die-back fungus was prominent in the region of the collar, a feature which is not specially stressed in the cases reported from Java and Ceylon. Seedling plants in baskets were involved in both the outbreaks observed in Malaya (Fig. 50); the stems of the plants were about nine to twelve inches in height, and the outer cortical tissues for about one inch above ground-level became blackened. Later, the whole of the stem tissue in this area became involved, and the stem and head of leaves finally falls over.

The description given by Petch for Ceylon specimens corresponds closely with the symptoms observed in Malaya, but the causal fungus is given as *Pestalozzia palmarum*, Cke. While this fungus is exceedingly common in Malaya, it has never been reported as occurring in the affection under consideration. However, it is generally admitted that both the fungi mentioned are but weakly parasitic so that it is possible that *P. palmarum* might cause symptoms similar to those of *Diplodia* in *Hevea*, although the dark-coloured hyphae produced by the latter fungus could never be confused with those of *Pestalozzia*.

The disease, in Ceylon, was found in nursery beds and, as Petch points out, the same ground is often continuously used for nurseries, and consequently the soil becomes sour and quite unfit for use in nursery beds. Such conditions favour the development of weakly seedlings which are unable to resist the attacks of weakly parasitic fungi.

In both cases observed in Malaya, the seedlings were in baskets so that the soil was used once only. Large, permanent, adjoining nurseries, containing ordinary seedlings for use as stumps, were free, or had only a few cases of the disease as compared with the basket seedlings.

A careful inspection of the beds in which the basket seedlings were growing showed in one case only a heavy infection before planting. The remaining beds of basket seedlings in other situations were quite free.

There seems little doubt that the heavy infection in certain beds was primarily due to the planting of seedlings obtained from a previously infected bed. The writer holds the opinion, however, that a considerable number of seedlings first showed definite signs of infection in the fields, and that considerations such as soil sourness en-

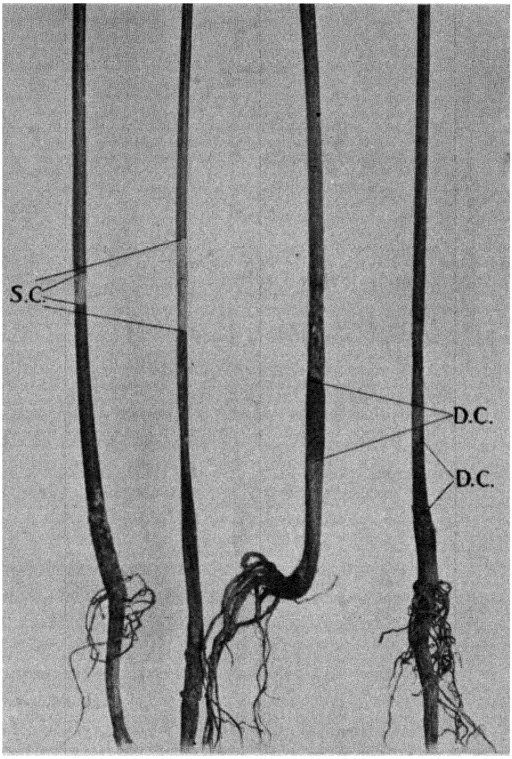


FIG. 50.—Showing typical appearance of seedlings affected by excessive ground heat, before bending to collapse finally. Note root development.

S.C., Woody tissues exposed because cortex has fallen away.
D.C., Showing discoloured stem areas before affected cortical areas have fallen away from the wood.

abling a weakly parasitic fungus to attack weakly individuals will not account for the whole of the symptoms observed.

Butler calls attention to a somewhat similar disease on Tea seedlings, and though no parasite has been found in connection with the disease in India, yet in Java and Ceylon a fungus has been found on the diseased parts. Both in Java and India the original cause of this

disease has been assigned to alternations of high humidity and great heat. The conditions were most closely examined in India and it was found that the disease, i.e. on Tea seedlings, occurred in a season in which there was first a long drought with considerable heat towards the end, then continuous, heavy rain for about a fortnight, followed by several extremely hot days. During these, the disease became evident. The trouble was attributed to climatic changes in India, but in Java and Ceylon the fungus present is considered to be the direct cause, Javan opinion holding, in addition, that abrupt climatic changes prepare the way for the attack.

Steinmann has directed attention to this type of affection during dry-weather periods. He states that this disease symptom will often occur in nurseries sporadically, but that it is not of a serious nature. The symptoms he describes as follows:

The leaves of the affected plants, already ten to fourteen inches in height, begin to pale, turn a dirty yellow and often drop off. At some distance over the root-collar the plants also show a circular nick, one or two centimetres wide, the bark of which is discoloured and dries up completely. The young stem is thereby practically ringed so that below this spot the nutrient supply is broken. In a few cases only will the plants perish completely; in most cases callus tissue grows from both sides and the dried-up belt is thus gradually overgrown. If this dried-up belt is situated on the stem above the root collar (which is usually the case), new roots are developed from healthy stem tissues above it and the plant may thus be enabled to carry on. But sometimes when damage has been done to deeper living tissue, the stem dies off and falls over; new shoots will then, however, sprout again from below, but these new shoots may in turn become affected.

In some cases the plants first affected show cracks running lengthwise down into the wood; later the tissue dies and the bark dries up completely in that spot. Fungus growth always occurs there. The fact that this discoloured belt is, with surprising regularity, found at the same height in all plants attacked, however, makes one suspect that another and primary cause has preceded the fungus infection. These fungi (chiefly *Phoma*, *Colletotrichum* and also *Diplodia*) all turn out to be of a very secondary character.

The consensus of opinion appears to be that a purely physical cause is to be regarded as primary, viz. excessive heating by solar heat, and that the fungus is purely secondary and often superficial. While no definite work in the shape of isolations or inoculations was undertaken by the writer, it is agreed that the primary cause is scorching, but, in Malaya, it is only another case of the association of the *Diplodia* die-back fungus with overheating of cortical tissues.

Swart observed a similar occurrence also on young basket plants, that at the start of the dry season had been transplanted from the nurseries

into the fields. In this case, it is reported the early stages were sterile, whereas at advanced stages a fungus was found which, according to our experience in such cases, often occurs secondarily. The fact that the plants that were kept in the nurseries did not show this symptom of disease and that those plants that had been transplanted a few months earlier remained perfectly healthy, did not make it seem probable the disease was due to a parasitic fungus; everything seemed to indicate that it was due to a purely physical cause, viz. scorching by the heat of the sun.

Steinmann suggests that the usual cause of the disease is that the seedlings have been planted too deep, so that the part of the stem that is still green and unprotected against external influence by a cork layer, comes into contact with the greatly heated soil surface and the hot layer of air immediately over it, and so gets burned. In most cases in which discoloration just over the ground occurs, the excessive reflected heat has first damaged the tissue of the stem, whilst wet weather following on the hot period stimulates the growth of fungi in these spots.

Similar types of damage caused by overheating have been reported from temperate regions by Hartley.

The disease, or affection, has never caused serious damage in Malaya, and removal and destruction of all the affected plants is all that is required.

Die-back of Snags and Spear-head Wounds at Junction of Stock and Scion

These two affections can be treated under one heading. Both of them have to be considered as dependent upon and subsequent to the operation of budding, and in both cases, the ashy-grey discoloration typical in all woody tissues attacked by the *Diplodia* die-back fungus is conspicuous in the affected tissues.

The budding operation should be undertaken preferably on young rubber trees from twelve to eighteen months old. It is desirable to carry out budding at as early an age as possible, so that when it has been successfully accomplished, and the stock finally pruned, only a comparatively small wood surface, from one to one and a half inches in diameter, is exposed. A wood surface of this small size is rapidly covered by the ingrowing callus. Healing may be completed in six to nine months' time and there is no special necessity to lay emphasis on the matter of a protective covering for the wood surface exposed by the final pruning.

While it is generally recognised that young stumps or seedling stocks are most easily worked, there are numerous instances where

obstacles have arisen to delay the budding programme and the plants attain the age of three to four years before the operation can take place. Cases are known where budding has been done on even older trees, and in these a very large wood surface is exposed at the final pruning, which must necessarily take a long time, even years, to heal over.

The fundamental principles of disease treatment are all against leaving such large exposed wood surfaces unprotected. The usual treatment has been, in Malaya, to paint the exposed surface with a fungicidal solution of one of the usual proprietary coal-tar derivatives soon after cutting, and later to apply asphaltum-kerosene mixture. As long as the asphaltum layer remains unbroken, the scion tissues should not be penetrated.

Trouble was soon experienced in the field, as a result of die-back fungi gaining entry to the stock tissues and causing the death of both bark and wood tissues. The favourite point of entry is on the side opposite to the bud patch; the reason for this is that the wood and cortical tissues in this region gradually begin to dry out because of the strong pull exerted on the water supplies by the rapidly developing scion. This die-back may, if neglected, develop and grow downwards into the scion tissue to a point well below the level of the bud patch, and occasional cases have been obtained where the die-back had penetrated into the root system. Several fungi are prominent on such rotting scion tissues; two common ones are *Polystictus occidentalis*, Kl., and *Lentinus lecomtai*, Fr., while in almost every case the ashy grey discoloration typical of the presence of the *Diplodia* die-back fungus is prominent. The percentage infection was often well over 30 per cent (Figs 51 *a* and *b*).

Anatomical investigations conducted on the tissues immediately covered by the asphaltum layer showed the pycnidia and spores of *Diplodia* developing quite normally, embedded in the interior of the asphaltum layer (Fig. 52). When the asphaltum layer was removed carefully from the wood surface, a distinct layer of *Diplodia* hyphae was found covering and growing downwards to penetrate into the woody tissues (Fig. 52). From these observations it was concluded, quite justifiably, that an asphaltum cover had many disadvantages and a search was made for a better medium.

Laboratory experiments indicated that a mixture of grafting-wax with 5 per cent of sulphur would be a great improvement. Twelve different covers were tried and the entwas-sulphur mixture, with reference to preventing entry of the *Diplodia* die-back fungus, was outstanding. Under the same conditions, stripped surfaces covered

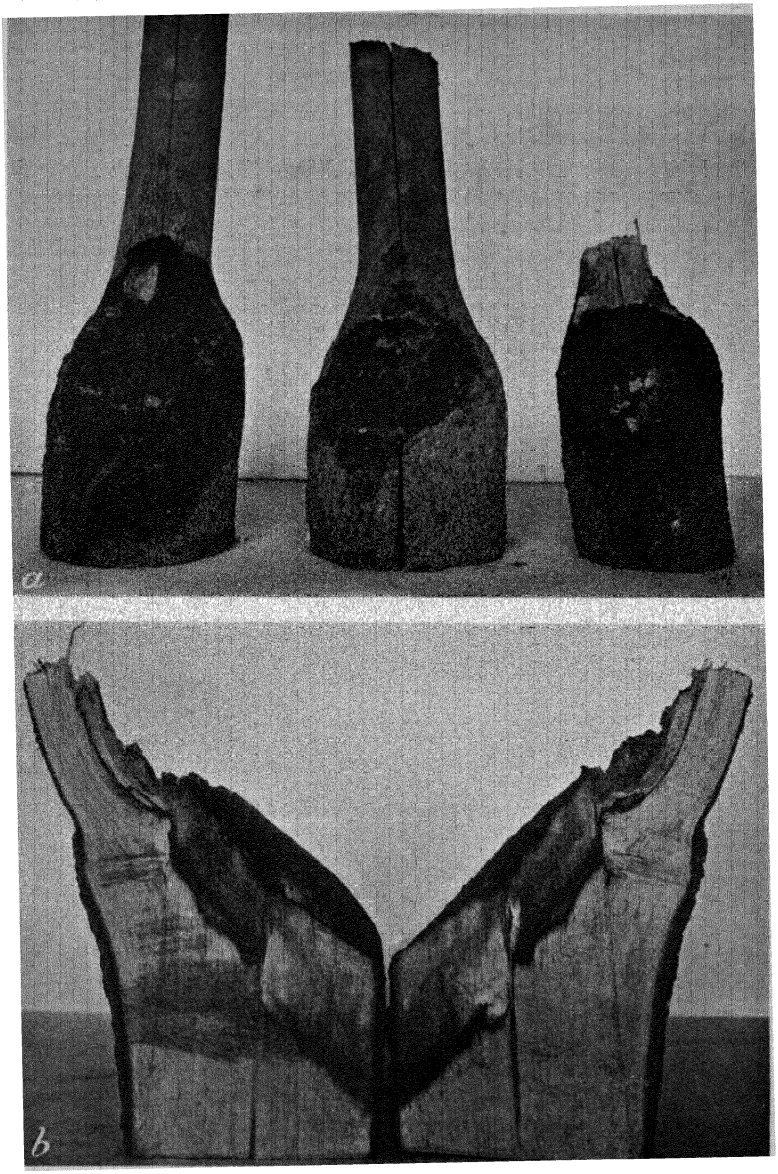


FIG. 51.—(*a*) Showing ordinary appearance of snag die-back. (*b*) Showing one case of (*a*) split open. In this case there has been some slight penetration of scion tissues, but this is comparatively small in amount compared with the penetration of the fungi concerned, into the stock tissues.

with entwas-sulphur mixture were clear of invasion after six months' exposure, while those covered with home-made white lead paint, a mixture recommended for wound-dressing of orchard trees in England, were badly invaded after a period of three to five weeks. The wax-sulphur mixture was recommended for use in the field and the early results were very encouraging, for there was a notably rapid formation of the callus ring and there seemed no reason to suppose that the ingrowing callus would not continue to develop and finally enclose the exposed stock tissues. While the advantage provided by

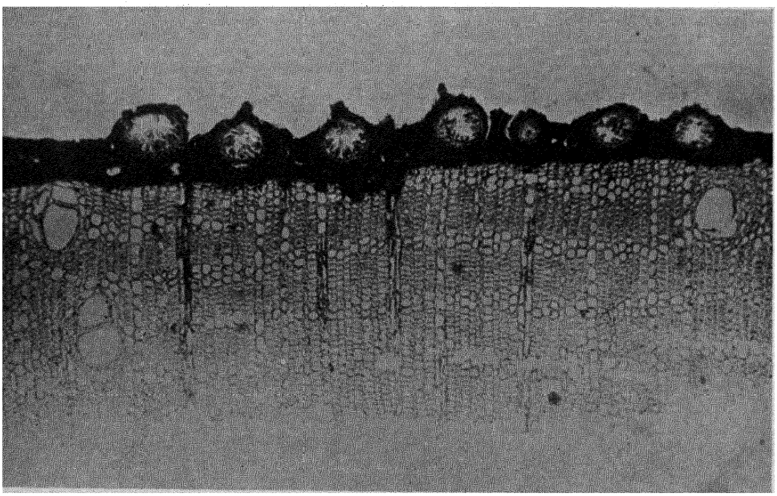


FIG. 52.—Section through asphaltum layer, covering woody tissues which are exposed when the pruning is done, after budding has been performed successfully.

Note numerous *Diplodia* pycnidia with spores, developing normally in the interior of the asphaltum layer. Discoloration of the medullary ray cells can be made out if looked at carefully, and these are *Diplodia* hyphae which have entered and are penetrating through the woody tissues.

complete and continuous shading was fully appreciated, the treatment sent up the costs to a considerable degree and, during a severe depressed period, insistence on the advantages of shade was not maintained.

The ultimate results of field experience was just as bad as in the previous case with the protecting cover of asphalt. If not given shade, the wax is melted, probably daily, by the heat of the sun, and some of the melted wax runs over from the cut surface at the lower edge on to portions of the bark of the stock, on the side opposite to that on which the budding is done. These bark areas, which become covered

with wax, were either burnt or smothered; in any case die-back set in again, and the position was by no means improved.

Following this experience, attention was naturally directed to the question of overheating and its prevention by shade. It seemed desirable to enquire into the differences of temperature likely to arise between black and white surfaces, for it is well known that the former absorb while the latter reflect heat. For this purpose, large test-tubes containing water were provided with rubber corks, through which

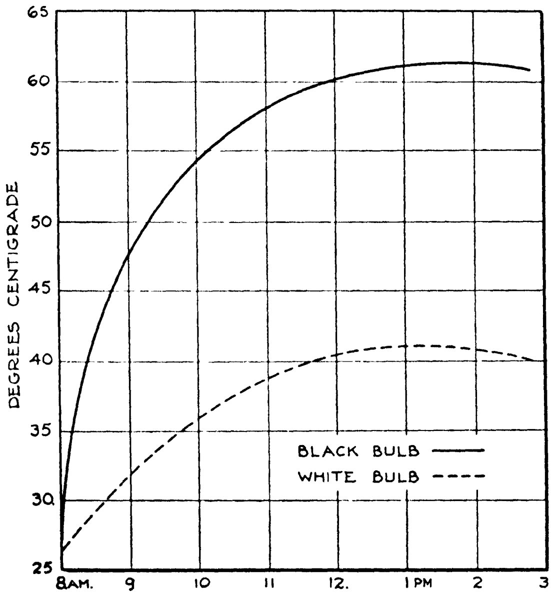


DIAGRAM X

thermometers projected with the bulbs lying covered by the water. The outside of the tubes were coated with materials of various colours. The tube covered with the asphaltum-kerosene mixture represented the black surface, while a thick layer of whitewash on the outside of one of the tubes represented the white surface. The test-tubes, when prepared, were put out in the sun in an enamelled tray, lying on a thick pad of cotton-wool.

The graph given in Diagram No. X shows the results obtained, and they were rather unexpected. The trays were placed in the open just after 8 A.M. and all showed the same temperature of 26° C.

Taking into consideration only the black and white test-tubes, the difference in hourly temperatures was as follows:

	Black Bulb	White Bulb	Difference
9 A.M. . .	47·5° C.	34·0° C.	13·5° C.
10 A.M. . .	54·0° C.	36·0° C.	18·0° C.
11 A.M. . .	58·0° C.	38·5° C.	19·5° C.
12 NOON . .	60·0° C.	40·5° C.	19·5° C.
1 P.M. . .	61·0° C.	41·0° C.	20·0° C.
2 P.M. . .	61·5° C.	41·0° C.	20·5° C.
3 P.M. . .	60·5° C.	39·5° C.	21·0° C.

The results show that the difference in temperature after only two hours' exposure is 18° C. and thereafter a fairly constant difference of about 20° C. Converted into Fahrenheit, this difference is equivalent to 68° F.

The large difference in temperature brings this particular type of decay into line with the other affections described in this chapter. The effect of overheating on the thin-walled, delicate cells composing the ingrowing callus ring cannot be ignored, and this is probably largely responsible for the presence and development of the *Diplodia* die-back fungus in the wood tissues of the stock. Enquiries have elicited the information that in French Indo-China the affection known as snag die-back has been very troublesome, largely because, in that country, a prolonged dry period is experienced during part of the year. The trouble is now no longer acute because budding is always done on the side of the stock facing north-east or south-west, so that there is some measure of protection against the full force of the direct rays of the sun; this is supplemented by an annual painting with whitewash, so as to completely cover the pruned surface, which had been previously treated with tar. Also seeds or cuttings of climbing legumes are planted at the base of the stock and allowed to grow up and over the wood surface exposed by the pruning, so as to provide shade; these climbing plants are prevented from growing over the developing scions. There seems little doubt therefore, that in these cases field-experience supports laboratory findings.

A feature of some importance which has emerged from the work in the field is that the final pruning cuts should be made at a slope, not less than 45°. Even a steeper slope seems to encourage the more rapid development of the callus.

This is important because the die-back in the stock tissues may have progressed to a distance of five to six inches below the place where budding was done. In such cases, a very steep angled cut

would have to be made to cut out the diseased tissues efficiently: this can be done with safety, if there is no sign of diseased tissue in the vicinity of the bud patch.

Protection of Pruned Surfaces in Budding Operations.—(*a*) If budding is carried out on trees not older than 1½-2 years of age, it is a matter of personal choice as to whether a protective layer should be used or not. Even if the pruned surface is not treated in any way, it is extremely unlikely that any damage would be done if the trees are vigorous and growing under normal conditions.

(*b*) Buddings worked on large stocks should be treated as indicated above in the text. The final cut should be made at an angle of not less than 45° and an application of a disinfectant solution on the cut surface should be made the same day. On the day following, the cut should be covered with tar or an asphaltum mixture. It is stated by some estate managers that only the wood surface should be treated with the wound cover, while the cortical ring should be left untouched as far as possible. This may be good advice and is perhaps well worth trying, but the writer cannot speak from experience. After a short time, more especially on the approach of dry-weather periods, the black surfaces should be given a coat of whitewash; once applied, this white surface should be maintained. Shade, provided in any suitable manner, will encourage the rapid development and early closing-over of the callus ring, It will be remembered that the use of whitewash as a fungicide for the control of mouldy rot was rather ridiculed in the section dealing with that disease, but if readers have followed the explanations given above, there should be no possible chance of confusing the issue. A whitewashed surface is less prone to excessive overheating by the direct rays of the sun. The point is an obvious one, but unless special mention is made here, it is possible that some attempt will be made to show that if whitewash proves of utility in one connection, there can be no absolute objection to its use in another. The point is that whitewash cannot be considered as a fungicide, or even as a disinfectant, and for mouldy-rot treatment in mature rubber areas it cannot possibly prove of permanent value.

Treatment of Snags already suffering from Die-back.—The only difference from the suggestions made above refers to the actual cutting-out of the diseased tissues. The angle of cut necessary to clear out all diseased tissue may be as steep as possible. In many cases, even a very steep-angled cut will not take out all the diseased tissue. If this is so, the diseased tissue should be allowed to remain and must on no account be chiselled out, more especially if it happens to be in

close proximity to the point where the scion actually joins the stock. After the cut has been made, the instructions given above should be followed.

Spear-head Wounds at Junction of Stock and Scion.—This affection is merely a variant of snag die-back, in which not only the stock

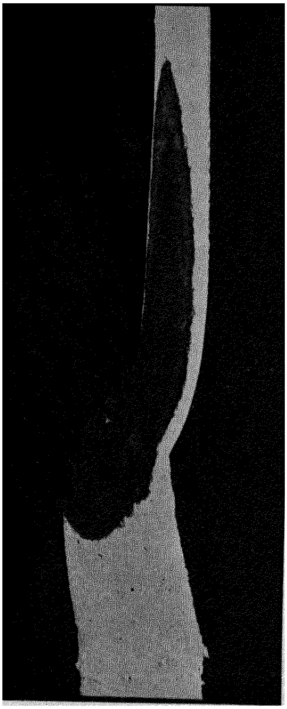


FIG. 53.—Showing typical appearance of spear-head wounds. To obtain the necessary contrast for a photograph a coat of whitewash has been applied around the wound, on unaffected tissues. Note the lengthy discoloured wound formed in the scion tissues.

tissues but the scion tissues become affected with the die-back fungi already mentioned. In so far as the scion is involved, this type of affection may have more serious consequences than the snag die-back, more especially as the black lines, characteristic of the presence of *U. zonata*, are usually present. The scion tissues involved are those on the side facing the stock, and if the tree is in vigorous health, the healthy cortical tissues commence to form a covering of callus tissue, which rolls in from both sides, forming a typically shaped spear-head

wound (Fig. 53). High-percentage affections have been recorded from a few estates and, at first, the writer was extremely pessimistic regarding the number of likely recoveries. However, good natural recoveries have been made in practically all cases.

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CHAPTER XVII

MISCELLANEOUS

Spottings in Prepared Rubber—Para-Nitro-Phenol as a Mould Preventive—Rust—Abnormalities—Regeneration of Tissues after Wounding; Copper Compounds as Spraying Mixtures for Diseases of Rubber Trees.

SPOTTINGS IN PREPARED RUBBER

THE first problem the writer was called upon to deal with on arrival in Malaya was the outbreak of extensive epidemics of coloured spots in pale crepe and pale sheet rubber. These were the types of rubber commonly manufactured about 1912 and for several years afterwards. Later, the introduction of the present practice of smoking rubber rendered the problem a matter merely of academic importance.

The main point of interest shown by the investigations of Bancroft and the writer was that the coloured spots were caused by the development of fungi *within* the substance of the prepared rubber. These fungi are commonly occurring ones, usually chromogenic organisms, and they find their way into the latex before coagulation. The spots were of various colours: red, black, blue-black, dark blue, yellow, violet; there were also transparent and opaque spots. As will now be realised by readers, fungi will not develop in the absence of a sufficient degree of moisture, and delayed drying was shown to be the main cause of the trouble. Inefficient drying was closely associated with the ineffective design of the drying-sheds in the earlier days of the rubber plantation industry, for as often as not they were but temporary structures.

Eaton gives the following probable reasons for slow drying:

A badly ventilated drying-room.
Excess of sodium bisulphite.
Insufficiency of sodium bisulphite.
Too thick a crepe.
Storage in a damp place or on cement floors.

It may be pointed out here that coloured spots may develop after drying and packing, while the rubber is in transit, on account of accidental wetting of the cases with rain, sea-water, or being stored in the damp hold of a ship.

The obvious remedy for preventing the development of these coloured spots is proper drying. There is no necessity to detail the methods which have been utilised for preventing the development of the spots by the addition to the latex of chemicals which are inimical to the development of fungi.

1 part of formalin to 800 parts, or 1 pint to 100 gallons, of latex has been used successfully in spot prevention.

Chinosol has been recommended for use in 1 per cent solution, but this chemical is comparatively expensive.

The following fungi have been mentioned as causal agents of these coloured spottings:

Causal Fungi	*Colour of Spotting*
Monascus heterosporus (Schroet.)	Red spotting
Chromosporium crustaceum, Sharples	Black spottings
Trichoderma koningi, Oudem.	Blue-black spot on crepe
Penicillium maculans, Sharples	Yellow spot on sheet
Spondylocladium maculans, Bancroft	Yellowish-red? or dark-green or almost black spot?
Fusarium sp.	Violet spots on sheet
Botryodiplodia theobromae, Pat.	Dark-blue spot
Mycogone sp.	Red flush on sheet
Penicillium and *Aspergillus* spp.	Transparent spots
Eurotium candidum, Speg.	Opaque spots

After preparation, rubber of any description will develop mouldiness if stored under damp conditions, or if it comes in contact with water, either rain or sea-water, during shipment or transit. The moulds which develop are those commonly appearing on domestic articles when kept in a damp state in the tropics, such as the green moulds (*Penicillium* and *Aspergillus* spp.) which appear on damp shoes, or the yellow and black moulds (*Sterigmatocystis* sp.) which grow luxuriantly on damp bread. There is only one satisfactory method of preventing mould development on pale rubber, and that is by keeping the rubber under conditions so dry that the growth of mould is impossible. For the prevention of mould growths and "rust" on smoked sheet, the use of a solution of para-nitro-phenol has been found to be effective. Eaton recommends its use as follows:

Para-Nitro-Phenol as a Mould Preventive

Para-nitro-phenol has been found to be effective in preventing the development of mould growths and "rust" on smoked sheet.

It is not recommended in the case of pale crepe, since pale crepe after treatment becomes discoloured on exposure to light.

Methods of Application

1. *Addition to Latex.*—The substance is somewhat difficult to dissolve in water, and if it is desired to incorporate it with latex it may be mixed with the coagulant. A 1 per cent solution (i.e. 1 lb. dissolved in 10 gallons of water) is recommended, in the proportion of 1 volume of the 1 per cent solution to 60 volumes of standardised latex (i.e. latex diluted to a dry rubber content of 1¼-1½ lbs. per gallon). It can be used with acetic or formic acids or with sodium silico-fluoride.

Owing to slight impurities in the commercial product, the solution should be filtered through a fine cloth in order to remove any insoluble impurities before it is added to the latex.

2. *Soaking method.*—An alternative method of application which is more economical and is recommended in preference to the direct application of the solution to the latex, is to soak the freshly-machined sheet in a solution of the chemical. For this purpose 3¼ ozs. of the chemical are dissolved in 20 gallons of water (i.e. 1 part of the chemical in 1000 parts of water).

The freshly-machined sheets are placed singly in the solution and all the sheets are allowed to soak for about half an hour. The sheets are then removed from the solution and allowed to drip for about two hours in a well-ventilated but a preferably shaded situation, before being placed in the smoke-house.

In order to ensure complete immersion of all the sheets, a weight of some kind should be placed on the top of the sheets. The object of placing the sheets singly in the solution is to ensure that the whole surface of each sheet comes in contact with the chemical. If a mass of sheets is placed in the solution, the solution will not be absorbed by the sheets in the centre of the mass.

The above quantity of solution is sufficient for the treatment of two batches of 100 lbs. of sheet. If only one batch of sheet is soaked in the solution on one day, the solution may be kept for the treatment of another similar batch of sheets on the following day. The solution should then be discarded and a fresh solution used for the treatment of further quantities of sheet.

Notes

1. Para-nitro-phenol is usually shipped in drums and is in the form of a cake which contains a certain proportion of moisture. The most convenient method of handling it is to place the cake in any suitable vessel (e.g. a Shanghai jar) for about two days, after which it can be crushed easily into a powder.

2. Samples of rubber treated with this chemical may be sent to the Institute for tests for mould development. The method of application of the chemical should be stated.

3. The sheet should be packed as soon as possible after removal from the smoke-house, preferably after 10 A.M., when the atmosphere is warm and less damp than in the early morning. Sheet which is stored in the open

absorbs moisture more rapidly and to a greater extent than sheet which is packed, and such moisture absorption increases the liability to mould development. All cases should be sun-dried before being packed and, after packing, should not be stored in direct contact with a cement floor. If sheet has to be stored on the estate and the store is badly sited, it may be necessary to adopt both methods of application of para-nitro-phenol.

Rust

This subject is referred to since Hellendoorn held the view that the deposition of a film of serum substances on sheet rubber causes "greasiness" and that rust is formed by the decomposition of this film by a micro-organism. The view held at the present time is stated by Eaton as follows:

> Rust is caused by the decomposition of serum, which exudes from the sheet during drying in the early stages of smoking. Rapid surface-drying, by hanging the sheets on racks in a well-ventilated place for about two hours before placing in the smoke-house, will usually remedy this defect. Soaking the freshly-machined sheet in a solution of para-nitro-phenol before smoking will also eliminate both "rust" and moulds.

Weir, in his annual report for 1928, draws attention to many varied, miscellaneous matters. These are of minor importance but it is necessary, for the sake of completeness, to refer to them. The following notes are largely copied from Weir's report:

Abnormalities

Hevea is influenced by different growing conditions, and hereditary or inherent impulses may develop abnormalities of various kinds.

(*a*) *Fasciation.*—The flat band-like branches simulating ram or moose antlers are observed to be inherent in certain individual trees and are produced at successive intervals without the influence of outside agencies. A tree has been studied on which these fasciations had been pruned back to the parent stem. New shoots had developed at this point and these were fasciated. The abnormal branches which had not been pruned but which had died back to the more cylindrical part of the branch, as they always do, had regenerated shoots below the dead parts. These also were fasciated. These observations imply an inherent force and not external agents as the cause. Fasciation has been artificially produced in *Hevea* by mechanically manipulating the terminal bud and by forcing growth into a single lateral bud. Seedlings with the tops heavily infested with mites occasionally produced bandlike terminal or lateral structures due to the concentration of the mites on one side of the shoots.

(*b*) *Warty Bark.*—In rare instances peculiar types of hypertrophies of the bark of *Hevea* are found. In one type the bark bears flat-topped, pyramidal,

4- or 6-sided, laminated warts ranging in height from ¼ to ½ an inch. These warts, which are composed almost entirely of cork, may be uniformly developed over the entire surface of the older parts of the tree or may occur singly or in patches here and there. Trees having the above characteristics have been located and will be used for propagation purposes in a general study on disease resistance and inheritance.

(c) *Diseases of Catch Crops.*—The occurrence of some of the common root diseases of rubber on catch crops is of interest to planters but should not be considered in a serious light. A comprehensive system of control should take into consideration the fact that any condition which increases the amount of organic material, dead or living, in the soil may be expected to increase the incidence of root disease. The fact that the roots of catch and cover crops are attacked is an indication that there is more inoculum in the soil for a particular site than is desirable. This is a condition in most cases over which the planter may previously have had little control. This being the case, more attention should now be given to keeping the base of the trees free from disease. As stated elsewhere, the basic principle of root disease control is embodied in any scheme that will prevent infection of the basal parts of the tree. If this is done effectively much of the work on the inspection and elimination of lateral roots may be greatly reduced.

The following fungi have been recorded on catch crops, viz. *Fomes lignosus* on Coffee, Tea, Tapioca, Oil Palm, Coconut Palm, Gambier and Kapok. *Fomes lamaoensis* on Coffee, Tea and Kapok. *Ganoderma pseudoferreum* on Oil Palms.

(d) *Cover Crop Diseases.*—What are probably the four principal fungous diseases of cover crops have been investigated in a preliminary study both under field conditions and under controlled experiments in pots. *Sclerotium rolfsii*, Sacc., has either been found in nature or inoculated on *Vigna oligosperma* (=*Dolichos hosei*), *Calapogonium mucunoides*, *Centrosema pubescens*, *Centrosema plumieri*, *Pueraria javanica*, *Mimosa invisa*, *Crotalaria anagyroides*, *Crotalaria usaramoensis*, *Crotalaria striata*, *Tephrosia candida*, and *Leucaena glauca*.

Rhizoctonia solani, Kuhn (=*Corticium vagum*), B. et C. (=*Hypochnus solani*, P. et D.), attacks *Vigna*, *Calapogonium*, *Tephrosia*, *Mimosa* and *Crotalaria*. *Pythium* sp. has been found to cause a die-back of *Centrosema*, *Indigofera* and *Vigna*. These fungi either attack mature plants or cause a "damping-off" or wilting of seedlings. The effect in the field is to cause the cover to die off in patches which may or may not regenerate, depending upon weather conditions.

(e) *Cover Crops: Relation to Disease in Rubber.*—Any condition that promotes a high moisture content around the base of the tree is favourable to root disease. Hence cover crops allowed to grow around the base of trees, especially young trees, are undesirable. The greater rapidity with which small jungle stumps decay when enveloped by a heavy growth of *Calapogonium* or *Centrosema* is a case in point. When covers are planted the base of the trees both large and small should be clean weeded. The fructifications and mycelial strands of *Fomes lignosus*, and the encrusting fruiting bodies and conidia-bearing hyphae of certain harmful fungi, have been

found growing in early stages of infection abnormally high on trees surrounded by a dense growth of cover.

Under a heavy mat of cover plants the strands of *Fomes* ramify over the surface of the soil and follow the tap-roots of the plants to their greatest depth, eventually causing their death. This condition has been studied in *Calapogonium* and *Vigna* and may be expected to occur with any cover.

These are extreme conditions and may be explained by the fact that the fungi were in great abundance in the soil before the covers were planted. Ordinarily *Vigna* does not form a very dense cover except in rich, moist, exposed situations.

That cover plants, whether herbaceous or shrubby, may be expected to afford an increase in nutrient substratum for mycelial development is by no means alarming. Plant cover plants by all means on certain soil types if possible. Nitrogen fixation, aeration and prevention of erosion are desiderata which outweigh all other considerations on most soils. On level, porous soils where there is little or no erosion and where the rubber with increasing age is gradually developing a rich natural forest soil the planting of cover crops, it would seem, is quite unnecessary.

Some remarks relative to cover plants and root diseases have been offered earlier, but a few comments may be added here on section (*e*), above. In view of the recent outbursts in respect of so-called "forestry methods" of cultivation, the remarks of a senior pathologist, with experience in many parts of the world, are of extreme interest. They show quite definitely that the essential principles of soil conservation are always kept well in mind by investigators working on pathological problems. They also show that *controlled* "forestry" methods are in no way antagonistic to the first principles underlying plant pathology. The date of their publication was in 1928, before the "forestry" method furore, which came about 1930 and has continued up to the present date.

(*f*) *Bark Bursts by formation of Rubber Pads.*—A peculiar feature noted in a field of nine-year-old bud-grafted rubber was a fair percentage of bark bursts which were caused by the formation of a large pad of rubber between the wood and the bark. Recent inspection has shown that in the great majority of cases the bursts originate in close proximity to the places where the ends of the wire cup-holders had been inserted into the bark.

The bark was thin, and to attach the cup-holders firmly the ends of the wire had to be forced deeply into the cortical tissues. In many cases the cambium, or at least the rapidly developing inner cortical tissues, must have been badly injured. This was proved by the large number of trees which showed knobs or swellings of secondary tissue along the vertical line where the ends of the cup-holders had been inserted.

The production of the large rubber pads (one measured 14 inches by 4 inches and was 2 inches across at the thickest part) is difficult to explain. As long as the latex remains sterile no coagulation will take place,

so it may be possible that latex infiltrates for a considerable period until bacteria make an entry; when this happens, coagulation occurs, and, as a result of the great expansion brought about, the bark above is forced outwards and ultimately bursts.

It is not possible to give a satisfactory explanation for all cases when rubber pads are formed between the cortex and the wood along the line of the cambial layer. When there is direct injury of the cambial layer and the laticiferous vessels lying in close proximity above it, latex will naturally infiltrate into the cavities so formed. The cambial layer provides the line of easiest separation of cortex from the wood and it is quite conceivable therefore that latex will collect in this position, and when expansion on coagulation takes place, separation between the wood and cortex would take place and gradually increase in size. The formation of rubber pads between the wood and cortex seems to be a common occurrence in patch canker, especially in those cases met with most commonly in Malaya, where untapped bark becomes affected following a lightning strike. The formation of rubber pads between cortex and wood are seldom seen in other panel diseases and are not likely to be found commonly in those which only affect recently renewed bark. South records that it has been proved by inoculations that the *Phytophthora* of black-stripe disease can produce blisters on the *untapped* bark at a height of about four to five feet up the stem. This statement refers to experiments carried out in Malaya. Petch deals with this subject under the heading of Rubber Pads, and the following extract is taken from his book:

Rubber Pads.—This name is applied to lumps of rubber found between the wood and the cortex. They are usually circular and plano-convex, being flat on the side in contact with the wood and convex on the other. The bark over the pad may crack longitudinally and some latex may exude and run down the stem. Sometimes the overlying cortex decays, but it frequently remains healthy, especially when it has cracked, and forms two raised lips, or flaps, over the pad.

No single cause can be assigned for these formations. It is probable that several agencies may induce this result, but a satisfactory explanation of the most general case has not yet been formulated, for it would appear that as a rule the overlying cortex is not diseased. It would, however, seem that one essential condition for their formation is that the cortex must separate from the wood before the pad is formed, The latex collects between the wood and the cortex, and it would appear obvious that it cannot collect there before there is a cavity between them.

Pads sometimes form beneath bark which has been killed by Claret-coloured Canker. If the dead bark separates from the wood, latex may collect behind it, presumably owing to the extension of the separation

along the cambium into the surrounding healthy tissue, but this is not of universal occurrence in the case of this disease. According to the accounts of Black Thread in Burma and Malaya, rubber pads are frequently formed beneath the decayed bark in cases of that disease, but they are not common under similar conditions in Ceylon. South states that it has been proved by inoculations that the *Phytophthora* of Black Thread disease can produce blisters on the untapped bark at a height of about four to five feet up the stem, the bark subsequently breaking up and disclosing a rubber pad underneath.

Quite an epidemic of rubber pads occurred in Ceylon during the time the Northway tapping system with a rotating pricker was under trial. In the system in question the bark at the base of the stem was scraped up to a height of eighteen inches, and the pricker was run round the stem in horizontal lines, the latex being collected in a channel at the base. To assist the flow of latex the scraped part of the stem was syringed with water. In many instances, blisters with rubber pads beneath them were formed, and these were cited as damage caused by the pricker, but it was clear that, in general, they were in existence before the pricker was applied, as they bore the marks of the pricker on the outer surface and often contained fragments of bark which had been pushed into them by the instrument. In some cases these blisters were the result of Claret-coloured Canker, but in others, though the bark died, no disease was traceable. All that could be said was that they followed the scraping and syringing.

An interesting case which probably has some bearing on the foregoing occurrence was noted during an attempt to infect *Hevea* stems with a possible parasitic fungus. A small patch on the stem was shaved flat, the fungus from a pure culture placed on damp cotton-wool, and this applied to the shaved patch and covered with a watch glass. As the weather turned dry, the cotton-wool pads were moistened daily. The inoculations were unsuccessful, but in several cases, both in the inoculations and the controls, a blister with a rubber pad behind it was formed, while the overlying cortex split longitudinally and latex ran down the stem. Thus the blisters and rubber pads were caused by keeping a small shaved patch of the stem continually moist.

Regeneration of Tissues after Wounding

This subject is one of considerable general importance and not only in a pathological sense. The operation of bud-grafting is absolutely dependent on regeneration of tissues, which can only be carried through successfully by vigorous plants. The subject has come into prominence recently as a result of researches carried out in the Rubber Research Institute of Malaya over the last two or three years and published by Sharples and Gunnery in 1933. The recent work carried out over the same period by Napper on root diseases has led to conclusions which also have some relation to this subject. Napper

maintains that the presence of wounds on a living root does not increase its susceptibility to those diseases caused by the *Fomes* type of fungi, which are responsible for the most serious root diseases of rubber trees in Malaya. This view can be accepted without reserve. He points out:

that entrance through a wound may be impossible, the reason being that in contrast to wound parasites like *U. zonata*, the root disease fungi are very sensitive to competition and may be easily crowded out and killed by the common saprophytic fungi and bacteria which colonise open wounds in the field.

There may be supporting evidence for this, but it will be extremely difficult to provide convincing and final proof, especially in the case of root diseases, that saprophytic fungi and bacteria, which colonise wounds in *Hevea* roots, are capable of crowding out the important fungi causing root diseases.

Several references have been made to the adequate repair mechanism possessed by *Hevea brasiliensis*. Most planters familiar with the "stripping" method, recommended in past years for the treatment of brown bast, could not fail to be impressed with the rapidity with which regeneration of new cortical tissues, to replace those "stripped" away, took place; further, when "stripping" was successfully accomplished the renewed bark areas which ultimately developed appeared eminently satisfactory for purposes of tapping.

It has always been assumed, until very recently, that successful regeneration of wounded tissues depended entirely on the successful functioning of the *cambium*. The researches mentioned above resulted in the discovery that, in the case of *Hevea* (and probably of numerous other woody plants), the cambium is not concerned in the regenerative process for quite an appreciable period of time after wounding has occurred; regeneration commences and is carried forward by a tissue system entirely different, and only at a comparatively late date does the cambium come into action. The subject is too technical to treat of in detail here, but it is undoubtedly one of fundamental importance. The *modus operandi* may be stated for those readers who desire to know the main facts. The following account is a slightly modified form of the one published in the *Annals of Botany*.

The regenerative process is practically the same in *Hibiscus nosasinensis*, L., and *H. brasiliensis*. The commencement can be more clearly observed, however, in the former, because tannin deposits, which interfere with clear definition of detail in *Hevea*, are absent. If a small bark area is stripped away from a vigorous plant signs of cell activity become manifest on the exposed wood surface two to

three days after stripping. In transverse sections it will be seen that the end cells of the medullary rays, which in *Hibiscus* are generally one to three cells wide, have become large, rounded, or oval-oblong with thin walls and sparse protoplasmic contents (Fig. 54). Between neighbouring medullary rays smaller cells of similar structure develop from wood parenchyma cells which normally would form xylem or wood elements. As a result of these activities the surface of the exposed wood becomes quickly covered with a layer of thin-walled cells, the most striking feature of which is their enormous size when contrasted with those from which they are derived. This proliferation of primary callus cells from the wood is accompanied by a similar

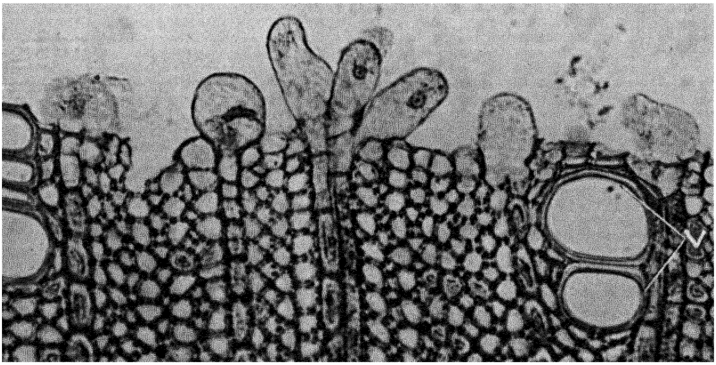

FIG. 54.—Proliferation of end cells of the medullary rays in the early formation of wood callus. Note large vessels of wood, V. × 200.

development from the cut edges of the bark bounding the wounds occasioned by the stripping (Fig. 55). It is safe here to say that, as in the proliferation of callus cells from the exposed wood surface, the elements of the medullary rays give rise to the greater bulk of the callus cells proliferated from cortical elements, and it appears that no callus cells at all are derived from cambial elements. At this stage the entire wounded surface is covered with callus tissue, the base of the cavity being covered with callus derived from the medullary ray cells of the wood, the edges being covered with callus of bark origin, using the latter term to include the whole of the cortical tissues (Fig. 56).

The proliferating phase above described is generally completed in about six days from the date of stripping, and at this early stage there is evidence of the downward extension of the phellogen or

cork-forming cambium, the continuity of which has been broken by the action of stripping. A further increase in thickness of callus tissue at the base of the cavity is brought about by normal cell division of

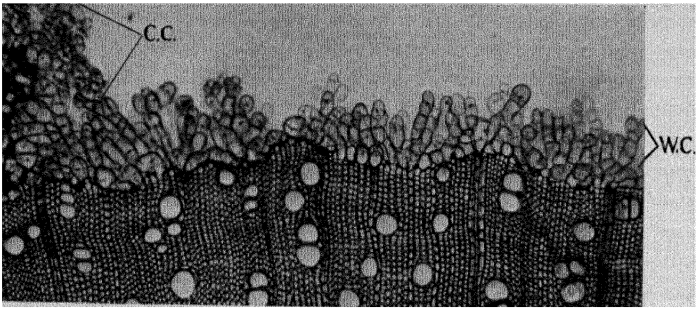

FIG. 55.—Later phase of callus formation. × 60.

C.C., Showing radially disposed callus tissue developing from bark tissues.
W.C., Callus developing on surface of wood.

the cells composing the callus tissue. Repeated division results in a more or less radially disposed series of cell rows, which are loosely aggregated at first, but later become consolidated by mutual pressure into a large-celled parenchymatous *cushion* covering the surface of

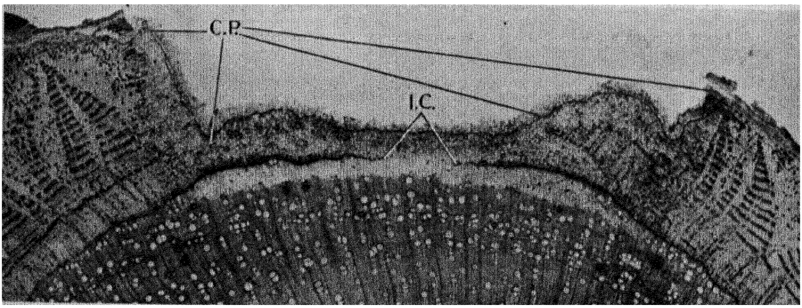

FIG. 56.—Completed phellogen but incomplete cambium reconstruction. × 18.

I.C., Unjoined ends of incompletely restored cambial cylinder.
C.P., Complete phellogen layer.

the wood. This cushion does not completely fill the cavity, the depth of which naturally varies according to the thickness of the bark. The phellogen, already developed in the bark callus mentioned above, now rapidly extends from the periphery inwards, just beneath the exposed surface of the callus cushion, the thin layer of cells thus cut

off to the outside becoming suberised, i.e. corky, to form a protective layer to the delicate tissue beneath. (The term delicate refers only to the fact that such thin-walled cells rapidly lose moisture under dry conditions, and desiccation and resultant death would take place rapidly.) The phellogen is completely restored in the way indicated, and with the complete formation of an outer suberised layer the dangers from desiccation are greatly reduced.

The second phase of callus formation occupies fifteen to twenty days, and in the stripped area there is still a complete absence of any sign of normal activity in the zone where the wood and bast forming cambium would normally lie. It is not an exaggerated view to take that the operation of stripping appears to result in the removal of the wood and bast forming cambium in the stripped area. But during the callus formation over the stripped area the normal activities of those portions of the stem unaffected by the stripping proceed as usual, and an appreciable increase in diameter of the wood, owing to normal secondary thickening, takes place excepting in the stripped area, where cell activity is, for the time being, concerned entirely in callus formation. The ultimate result is that the callus cushion appears to be sunk in the wood to a depth equivalent to the thickness of the woody tissue newly added since the stripping operation was performed. Coincident with the increase in thickness of the woody cylinder over the uninjured parts of the stem, the cambial ring appears to be carried outwards a similar distance, so that the severed ends of the cambial ring now impinge on the sides of the callus cushion some little distance from the original position at the time the bark was stripped. The last phase now ensues, viz. the development of a new cambial portion through the callus cushion to form a continuous cambial ring. The development proceeds from both sides at the points where the severed ends of the original cambium impinge on the sides of the callus in the cavity. The ends of the severed cambial ring grow towards each other through the callus cushion, sweeping across in the manner of a slowly closing diaphragm until the opposing ends meet and the cambial cylinder is thus fully restored.

With the complete restoration of the cambial cylinder the subsequent history is merely one of normal cambial activity, secondary thickening proceeding in the usual way. But preceding this, the outer, protective, phellogen layer is completed and the tissues of the callus cushion, in which the new cambial elements develop at a later stage, become adequately protected, so that the chances of the successful development of a continuous cambium across the callus cushion are greatly increased. If, as appears probable, the stripping results in the

removal of the actual cambium, it is not difficult to visualise the necessity for the development of some type of "bridging" tissue which will remain in contact with the severed ends of the cambial ring on both sides while the latter is being carried outwards by the continuous secondary thickening. The development of the callus cushion as a bridging tissue allows for the formation of the cambial ring in the exact position it would have occupied if stripping had not taken place.

Thus if an outer corky protective layer is formed across the callus cushion before the development of the cambium across it, the latter will seldom suffer injury. When a suberised corky layer is fully formed desiccation can affect the underlying cell layers only to a comparatively small degree, and as this proves the greatest danger during regenerative processes, little damage need be expected to take place to the actual cambial elements developing beneath in the callus cushion. Desiccation can affect only the large, thin-walled cells of which the callus tissue is composed, but in the presence of adequate supplies of moisture the callus cells developed by vigorous plants possess an inherent resistance to degenerative influences in the form of invading organisms, and therefore, while it may be possible, it is more likely improbable that saprophytic bacteria or fungi, or even parasitic forms, would cause any great interference with the regenerative processes going forward.

All investigators who have undertaken artificial inoculations on the roots of mature rubber trees are well aware that they seldom succeed, and in the writer's experience consistent success has only been obtained when *Ustulina zonata* has been inoculated into *large* wounds. There is little more to add beyond the remark that it seems preferable to rely on an explanation which has been demonstrated than on one for which it would be difficult to provide convincing proof. The suggestion of Napper's, therefore, viz. "that root disease fungi [of the *Fomes* type] are very sensitive to competition and may be easily crowded out and killed by the common saprophytic fungi and bacteria which colonise open wounds [on rubber roots] in the field", does not appeal strongly to the writer. This matter is referred to only because a journalistic writer in a local Malayan paper has drawn special attention to this particular view stated by Napper, and draws far-reaching conclusions therefrom, which cannot be accepted by the writer, and probably would not be accepted by Napper himself.

Copper Compounds as Spraying Mixtures for Diseases of Rubber Trees

Most books dealing with plant diseases give details of the method of preparation of the standard copper and sulphur compounds which are commonly used in agricultural practice. The names Bordeaux Mixture, Burgundy Mixture and Lime-sulphur Mixture are familiar to all interested or engaged in agriculture; lime and copper are the fundamental components of the two first-named compounds. No special reference to details of component parts or the method of the preparation of these compounds will be given in this work, for it is obvious they now take a very minor place in the economy of rubber plantations. Spraying mixtures based upon a copper compound, usually copper sulphate, require mention, because it is well established that the presence of copper salts, or of particles of metallic copper in prepared rubber, induces tackiness.

As copper spraying mixtures are never used in rubber plantations, it appears unnecessary to refer to the matter. But the use of Bordeaux Mixture, in the treatment of pink disease, was seriously considered around 1914, and it may be necessary to utilise spraying mixtures for the treatment of a rubber tree disease at some future date. It is advisable, therefore, to mention the work carried out in rubber-growing countries and the results obtained when Bordeaux Mixture has been used in such a manner as to ensure appreciable quantities being incorporated in the rubber after coagulation and preparation. This was performed by Brooks and the writer in 1914, and to make certain that Bordeaux Mixture had entered the latex, samples of rubber were prepared from latex into which the mixture was poured directly. The experimental rubber sheets were kept for nearly a twelve-months period, but no tackiness became apparent. Petch deals with the subject shortly, and the copy of his paragraphs given below, indicates that similar results were obtained in Ceylon. As Petch remarks, "the question of the employment of Bordeaux Mixture for diseases of rubber trees consequently remains open for further investigation", but it is not an urgent matter at the present date and is not likely to become one for a considerable time. Petch's observations are headed "The effect of Bordeaux Mixture on Rubber".

It is well established that the presence of copper salts, such as copper sulphate, or of particles of metallic copper, in prepared rubber induces tackiness. If rubber is washed with a solution of copper sulphate it becomes tacky, while if copper sulphate is added to the latex before coagulation, the resulting rubber changes into a resinous sticky mass when dry. Hence it is generally held that Bordeaux Mixture, which is the most

efficacious fungicidal spray available for general use, cannot be employed in diseases of *Hevea*, because it is a copper compound, and if traces of it get into the latex the rubber will become tacky.

The experiments which have been carried out to test this point have, however, not been attended by any such result. At Perideniya a row of twenty-five trees, tapped on alternate days, was well sprayed with Bordeaux Mixture. The trees were tapped with two cuts a foot apart on one-third the circumference, and the mixture was applied to the tapping surface to a height of three feet in such quantity that it ran along the cuts and down the vertical channel. Heavy rain fell five days after the spraying, and the rubber of that day's tapping, when analysed, showed 0·00016 per cent of copper in the biscuit, and 0·003 per cent in the scrap. For six months from the date of spraying, the rubber, which was all prepared in biscuit form, was kept under observation, but no case of tackiness was observed. The experiment has been repeated with similar results in Java and Malaya.

The question of the employment of Bordeaux Mixture for diseases of rubber trees consequently remains open for further investigation. It is possible that the conflicting results obtained in the experiments quoted depend upon the state of the copper in Bordeaux Mixture as opposed to that in copper sulphate. Before the adoption of Bordeaux Mixture can be recommended, research is required not only into its action on raw rubber but also into the behaviour of the rubber during vulcanisation and manufacture.

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SECTION 6

PESTS

CHAPTER XVIII

INSECT PESTS

White Ants (*Coptotermes curvignathus*)—Boring Beetles (*Xyleborus parvulus*)—Cockchafer Grubs (*Psilopholis grandis*)—Geometrid Moth (*Hemithea costipunctata*)—Limacodid Moth (*Thosea sinensis*)—Lymantrid Moth (*Orygia turbata*)—Caterpillar and Noctuiid Moth (*Spodoptera* sp. and *Tiracola plagiata*)—Psychid Moth (*Psyche* (*Acanthopsyche*) *snelleni*)—Scale Insects (*Lecanium nigrum, Pulvenaria* sp.)—Rubber Leaf Mite (*Tarsonemus translucens*)—Short-horned Grasshopper (*Cyrtacanthacris* (*Valenga*) *nigricornis*)—Crickets (*Brachytrupes portentosus*)—Rhinosceros Beetles (*Xlyotrupes gideon*)—Eumeces squamosus—Batocera rubra.

INTRODUCTION

THE animal pests of all plantation crops are largely comprised in the order *Insecta*. A very striking feature of the pest and disease situation in relation to rubber cultivation is the fact that, apart from the ravages caused by white ants, there are no major problems to be dealt with. This statement should be perhaps modified, because the cockchafer grub plague, though at present circumscribed in area, is described by interested parties as a potential menace to the industry. The writer, however, does not subscribe to this view.

The following insect pests have been recorded as causing damage to rubber trees:

Common Name	*Scientific Name*
White Ants	=*Coptotermes curvignathus*, Holmgr.
	=*Coptotermes* (*Termes*) *gestroi*, Wasm.
Boring Beetles	=*Xyleborus parvulus*, Eichh.
Cockchafer Grub	=*Psilopholis grandis*, Cast.
Geometrid Moth	=*Hemithea costipunctata*, Moore
Limacodid Moth	=*Thosea sinensis*, Walk.
Lymantrid Moth	=*Orygia turbata*, Butler
Noctuiid Moth	=*Tiracola plagiata*, Walk.
Caterpillars	=*Spodoptera* Sp.
Bag Worms	=*Psyche* (*Acanthopsyche*) *snelleni*, Heyl.

Scale Insects and Mealy Bugs	= *Lecanium nigrum*, Nietn.; *Pulvinaria* Sp.
Mites	= *Tarsonemus transluscens*, Green
Grasshoppers	= *Cyrtacanthacris* (*Valenga*) *nigricornis*, Burn.
Crickets	= *Brachytrupes portentosus*, Licht.
Rhinosceros Beetles	= *Xylotrupes gideon*, L.
Weevil	= *Eumeces squamosus*
Longicorn Beetle	= *Batocera rubra*

A large number of insects have been recorded as occurring on and perhaps damaging *H. brasiliensis*. The list given above contains those which have been found causing definite damage in Malaya. But insects may also cause losses in indirect ways, more especially on plantations where a cover crop or a mixed natural cover is allowed to develop. There are several recorded cases of the caterpillars of *Thosea sinensis*, Walk., a Limacodid moth infesting fields of rubber where certain types of grass have become established. These caterpillars feed on the grasses originally. They have tufts of irritating hairs on the upper surface of the body, and when these tufts of hair make direct contact with the skin great irritation is set up which may last for hours. It is extremely difficult to get the coolies to work in infested fields and, in the cases noted, tapping had to be stopped until the attack subsided. As the caterpillar stage of this insect may persist for about a month, 8½ per cent of the yearly crop is lost over infested areas from the commencement of the attack. Attacks may be recurrent and it is obvious that a large percentage of crop may be lost in any one year if further generations develop after the adult stage has once been terminated.

White Ants

Coptotermes curvignathus, Holmgr.
= *Coptotermes gestroi*, Wasm. (= *Termes gestroi*)

Pratt wrote in 1914:

> The plantation rubber industry which developed with phenomenal rapidity in the Malaya Peninsula has not been threatened with any serious insect pests. Before any considerable acreage had been planted it was generally considered that *Termes gestroi* would prove a menace to the industry and it was decided to offer the sum of £5000 for an adequate remedy against its attacks upon the Para rubber tree.

There is no doubt that at that time there was a good deal of justification for the alarm caused by this insect. Many plantations, especially those on low-lying lands, were losing a very considerable number of trees apparently through the attacks of *T. gestroi*. One estate lost on one occasion approximately 2000 trees of 4 and 6 years of age in the course of 15 minutes (i.e. blown over), the majority of which were found to be hollowed by *T. gestroi*.

The above describes the position in Malaya and Java, but Petch says that the white ant is not a pest on rubber in Ceylon and South India, because *T. gestroi* is not found in these countries. But as far as Malaya is concerned the white ant problem has never been successfully tackled and the position to-day (1932) is not materially altered from that of 1910–12. In the days when rubber was very profitable, clean clearing and following-up the runs made by the insects with a view to finding and destroying the nest, might have been an economical proposition, but such control methods are impossible with present-day prices, unless other important factors, i.e. treatment of root disease in young areas, are taken into consideration at the same time.

Our knowledge of the life history and control of the insect is still unsatisfactory, but a comprehensive series of control measures is being tried out in Malaya at the present time by Beeley. The results of this work are given at the end of this section.

Termites, which are popularly known as white ants, form a separate order of insects, the *Isoptera*, and are of considerable interest on account of their habit of living in communities much in the same manner as do certain species of bees and ants. The nest is known as the *termitarium* and contains numbers of individuals belonging to different castes, the members of each caste serving the rest of the community in their own particular manner.

The winged forms, which are only too familiar at the lights of houses in Malaya during certain periods of the year, comprise normal males and females. A male and female, or rather "king" and "queen", establish a colony and, from the ova produced by the queen, individuals are produced in which the sexual organs are aborted. The majority of these sexless termites are "workers" whose function is to construct and attend to the termitarium, feed the royal pair and the immature forms (nymphs), and, in certain species, to cultivate the fungus gardens. The workers are soft-bodied creatures and are quite blind, having to rely entirely on the "soldiers" for their protection. The latter have prominent hard heads and are equipped with powerful mandibles; their primary function is to keep off invaders whilst the workers repair any breach in the walls of the termitarium.

Once a colony is established, the queen produces ova at a prodigious rate; the abdominal segments of her body become greatly distended and she often attains an enormous size. The queen remains imprisoned in a cell with the king and the sole function of the latter is to fertilise the queen. The eggs are oval or cylindrical in shape and round at each end. As soon as they are laid they are taken charge of by the workers, who clean them and carry them to special nurseries where they are tended until the young nymphs hatch out and are sufficiently developed to take their allotted place in the nest. The development from the egg to the adult stage is gradual, that is to say, there is no definite larval and pupal stage as in the true ants; so that when they emerge from the egg they resemble in general form a termite rather than a grub, and it is through undergoing several skin moults that they attain the adult stage.

At certain periods of the year the sexed wing forms are produced in large numbers and, when certain climatic conditions obtain, they leave the termitarium at dusk, and those that escape destruction establish new termitaria.

About eighty species of termites are known to occur in the Malay Peninsula and doubtless others await discovery. Many of the species are very similar in appearance and their identification is often a matter of difficulty, and this, coupled with the paucity of literature on the subject, has led to confusion, and remarkably little detailed information is available concerning any but the two or three commonest species.

There are two closely related species of termites about which some confusion has arisen. One is *Coptotermes gestroi* Wasm. (= *Termes gestroi*) the other *Coptotermes curvignathus*, Holmgr. In connection with this, Mr. H. M. Pendlebury, of the Selangor Museum, Kuala Lumpur, informed the writer in a private communication that:

> much confusion has arisen over the identifications of *Coptotermes gestroi*, Wasm., and *C. curvignathus*, Holmgr. Wasmann's original description was not entirely adequate, and Haviland (1897), by misidentification, regarded *C. gestroi* as being one of the commonest pests on rubber trees, and several authors followed him uncritically. It was only when Holmgren (*Kungl. Sven. Vet. Akad. Handlingar*, Band 50, 1913, p. 77) examined Wasmann's type that he found the species which had been treated as *gestroi* (Auctt. *nec* Wasmann) was distinct in certain structural details; this he denominated *curvignathus*. The fontanelle is present in all castes of the *Mesotermitidae*, to which the genus *Coptotermes* belongs.

It appears therefore that *C. curvignathus*, Holmgr., is probably the most important species of termite as far as the rubber-grower in

Malaya is concerned. The soldier of *C. curvignathus* is somewhat larger than that of *C. gestroi*, 7·5–8·5 mm. as against 6–6·5 mm., and has a less oval head; the mandibles are more curved and the pronotum is 1 mm. wide against 0·65 mm. with *C. gestroi*. A small orifice is situated at the front of the head from which a milky white fluid is discharged. This is the fontanelle mentioned in the preceding paragraph.

The following observations were made undoubtedly on *C. curvignathus*; this should be noted, for it is difficult to decide which species Pratt was dealing with in his observations on *Termes gestroi*, for they do not tally with those offered here for attacks by duly authenticated *C. curvignathus*. Termites have often rightly been recorded in Malaya as causing damage to living rubber trees, though there appears to be a general impression that they confine their attention to diseased trees. Pratt says, with reference to *T. gestroi*, "that the original trouble is due in nearly every instance to fungus or bad drainage causing root-rot may be taken as an established fact". It may be stated quite definitely that there is no justification for the belief that healthy trees are immune from attack by *C. curvignathus*. This species appears to be common in Malaya in suitable situations, showing a strong preference for damp, low-lying land where moist soil conditions obtain; the rubber trees planted on peaty areas which carry quantities of buried timber are usually very seriously attacked. It has been found attacking young rubber showing no signs of disease, and if left undisturbed can inflict fatal injury within three or four weeks. During recent observations in Malaya, only young rubber was found attacked, but it is not suggested that this termite cannot infest mature trees.

On young rubber little variation is shown in the method of attack. First a mud tunnel is constructed on the trunk upwards for a distance of several feet (Figs. 57 *a* and *b*), and this tunnel is gradually extended laterally until the whole of the lower portion of the trunk is encased with mud. Repeated examinations of the lower termination of the tunnel, which usually stops abruptly about one or two inches above the surface of the soil, failed to give any indication of the point at which the termites emerged from the soil.

Once the mud wall has been completed the bark is attacked simultaneously at a number of points, but most strongly near the base of the trunk. The exudation of latex does not appear to deter the invaders, and the attack is usually continued until the whole of the lower part of the trunk is denuded of bark. Then the wood is penetrated and numbers of long vertical tunnels are constructed; this is

followed by an attack on the root system, by which time the tree is injured beyond recovery (Fig. 58).

Petch, writing of attacks by *Termes gestroi*, says:

T. gestroi usually attacks a tree below ground-level. Like the majority of termites, it travels underground by means of narrow galleries, and when one of these galleries happens to meet a root of a rubber tree the insects

FIG. 57—*a*, Showing mud tunnel, or covering, which extends upwards for several feet and covers a large portion of the lower part of the stem. After first appearance of the cover at ground level, the mud casing is built up very rapidly, reaching the height of several feet in a few days. Mud cover broken away for purposes of photography. *b*, Photograph to show where the strongest attack is made by White Ants, at base of trunk.

attack it. Lateral roots may be immediately attacked, or the insects may tunnel a gallery underneath the lateral until the tap-root is reached, into which they penetrate. Once inside the tap-root, the termites eat out galleries in the wood and advance upwards into the stem. The wood of the tree is hollowed out, and the cavity is filled with a comb which is built of the excreta of the insects, and is, in fact, the remains of the wood of the tree after it has passed through their bodies. Ultimately the tap-root is destroyed, the laterals hollowed out and the interior of the stem becomes

a termites' nest. The affected trees may then blow over, or fall over during rainy weather owing to the extra weight of the wet foliage.

When young bud-grafted trees are subjected to attacks by *C. curvignathus*, the upper limit of the mud wall may not extend beyond the point of union of stock and scion and the termites may concentrate their attack upon the snag. When, as is frequently the case, there is a good growth of cover it is very difficult to detect trees which are being attacked until severe injury has been done. From direct

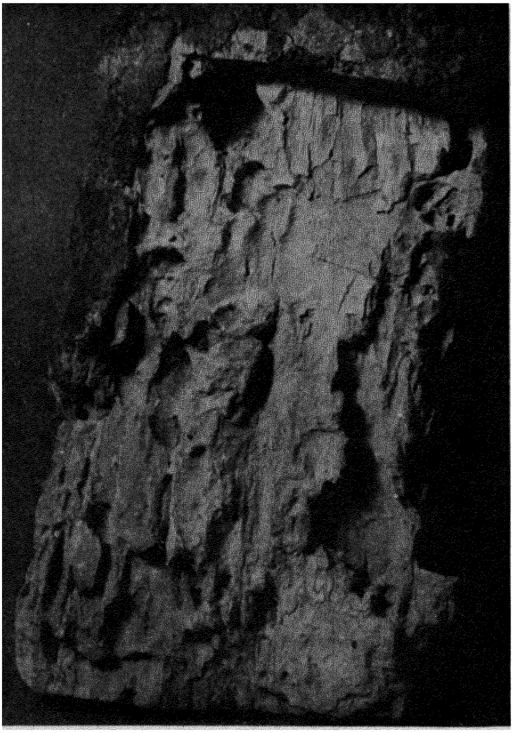


FIG. 58.—Showing the wood of a mature rubber tree hollowed out by White Ants. Photograph from a specimen in possession of the Imperial Mycological Institute.

observation, *C. curvignathus* can kill three-year-old trees within a month, and moreover, if treatment is not applied within a fortnight of the first appearance of the pests it is unlikely to be of any avail later.

It seems probable that these attacks are made from a central nest which may be situated some distance underground. The fact

that the large numbers of soldiers which are found in the early stages of an attack give place subsequently to a preponderance of workers indicates that communications are maintained between the termites on the tree and those in a central termitarium. The queens of *C. curvignathus* have been found but rarely, and there does not seem to be any evidence to indicate that this species makes permanent nests in young rubber trees. Pratt also states that there is no doubt that the queen of *T. gestroi* is extremely rare.

A further record of an attack on old rubber by a different species of termite was obtained in August 1932. The species concerned was *Eutermes* (*Hirtitermes*) *hirtiventris*, Holmgr. As far as could be ascertained by inspection, the method of attack is very similar to that employed by *C. curvignathus*, a mud wall being constructed over the bark some three or four feet from the ground and access to the wood is obtained under this cover. On this occasion about a dozen trees were being attacked simultaneously in a very small area and the attack was evidently in an initial stage. In a few instances the mud covering had been partially removed, presumably by tapping coolies, and this had sufficed to drive off the invaders. The mud covering was thin and brittle and presented a different appearance to that made by *C. curvignathus*, but this difference may be more apparent than real and attributable to different soil conditions.

In June 1911 a white ant attack by *Termes carbonarius* was reported which was stated to be killing newly planted stumps by stripping them of their bark. At that date attacks by this species of white ant were only noticed on rubber estates which were opened up on land previously under tapioca. No recent records of damage done by this species have been obtained. The correct name for *Termes carbonarius* is *Macrotermes carbonarius*, Hagen, which has reference to the comparatively large size and sooty colouring of the soldiers.

White Ant Control.—On certain rubber areas where conditions are exceptionally favourable to white ants, such as low-lying, peaty areas with much heavy, hard-wood timber submerged two to three feet deep in the soil, it is practically impossible to visualise any form of economic control. On such places the only method of control worth considering is the removal of all the submerged timber. Such an undertaking would involve deep digging to a depth of three feet, and this on any type of soil would be very expensive. On light, easily worked soil the cost of digging over to a depth of 3 ft. was $450 per acre in 1930, while another block of 3 acres dug over to three feet in 1931 cost $300 per acre. On heavy clay soils the cost would be appreciably higher.

At this stage a quotation from Pratt might be given:

Gestroi is an insect which in its native state may be called comparatively rare and springs up as a pest owing to the exceptional advantages that are afforded it when a new clearing is made. Although very persistent in localised areas it is unable to maintain for many years, and it certainly cannot increase, the high position which it eventually occupies in regard to the number of individuals that are produced in these exceptionally favourable circumstances; for, however suitable the rubber tree may be as a food for this insect, it is impossible for fresh colonies to be continually and successfully established on the living tree, which would be necessary for the continuance or the increase of the high standard of multiplication that has been reached. There must inevitably result from these gradually changed conditions a steady diminution of *gestroi* among the older rubber, and this slow but steady decline is frequently asserted to be due to perseverance in repelling their attacks on rubber trees. This latter fact may have some influence in aiding the decline of *gestroi*, but the inadequacy of the systems which have been employed, and for various other reasons, I am inclined to believe that the gradual abatement of *gestroi* as a pest on medium-aged clearings originally planted with rubber is mainly due to the altered and less favourable conditions rendering it impossible for this insect to maintain the same rate of increase which it has reached in circumstances known to be favourable for its multiplication. Were this not so, those rubber trees on existing plantations would, in a few years, be completely destroyed. It would nevertheless be most unwise to allow *gestroi* to have full sway on a young clearing, and await the decline of the pest, which would take something like 12 years, perhaps more. During this period it has ample opportunity to cause great harm to the trees.

Pratt's statements have been borne out by experience. In certain areas very favourable for the insect, economic control, no matter what the price of the commodity might be, is practically impossible. In the writer's experience, the number of areas worth clearing is small and such areas are seldom large in extent. On rubber plantations planted upon "lallang" (*Imperata arundinaceae*, Cyrillo) areas, no trouble is experienced from attacks by white ants, and they are not very prominent on undulating land, which forms the major portion of the area planted with rubber in Malaya. But the coastal alluvial areas usually show a heavy incidence of white ant attacks, and systematic treatment, which may be only repellent and not eradicatory, will help the young trees to attain the age when the danger zone is passed, i.e. when the conditions for the insects become less and less favourable for attack with time. On the alluvial, coastal or riverine areas, Towgood states that he found termitaria exclusively in Kumpas (*Koompassia malaccaensis*) and Meranti (*Shorea* sp.[1]) logs

[1] The local Malayan timber trade includes under this name almost all the softer Dipterocarps and many other unrelated timbers.

and roots, and chiefly in kumpas. Other timbers in which white ant nests have been found are given below:

Kayu Api	= ?
Merbau	= *Intsia* sp. & *Dialium laurinum*, Baker
Pataling	= *Ochanostachys amentaceae*, Masters
Jelutong	= *Dyera* sp.
Nibong Palm	= *Oncosperma filimentosa*, Bl.

The method of control proposed in the early days was to follow up the underground runways or galleries from the tree attacked to the log in which the principal nest was situated, and then to destroy the termites in the log by fumigating with arsenic-sulphur fumes (page 384) pumped from the Universal Ant Exterminator. Later, certain modifications were introduced, but these methods were not really successful and were very expensive. Certain subsidiary measures, such as (*a*) collection of queens, (*b*) flooding badly attacked areas, (*c*) selective removal of timber, have all been suggested.

At the present time the general control of white ants is based on the fact that conditions grow less and less favourable for the insects as the plantations reach maturity. Leaving out of consideration the hopelessly attacked areas, can an economic method be devised, possibly only repellent, which will give some assurance that mild attacks only are likely to develop? This leads to the consideration of the chemicals which have been tried in this connection.

A 0·5 per cent of mercuric chloride has been in common use for many years, and in some cases satisfactory results have been obtained. But in 1931 numerous complaints of the inadequacy, non-permanency and expensiveness of the treatment were raised.

For this reason it was suggested that Paris Green[1] powder, which had been used successfully against white ant attacks on Ceylon tea estates, should be experimented with in Malaya. In general, the use of this substance in Malaya has proved a decided improvement on solutions of mercuric chloride. If too large amounts of the paris green powder are used in heavy clay soils, which retain water tenaciously, there is a tendency towards bark-scorching and a subsequeut development of the root disease caused by *Sphaerostilbe repens*. This combination caused serious damage on one estate which practised the paris green treatment and later flooded the area for ten days. But, as pointed out when describing this root disease in an earlier section, *Sphaerostilbe repens* is the usual fungus which causes damage to the root systems

[1] *Report of Insect Pests in Ceylon during 1929*, Dept. of Agriculture, Sept. 1930, pp. 10-11.

after flooding. Experiments with mixtures of 50 per cent paris green and 50 per cent lime show that this mixture gives passable results; a mixture of wood ashes 30 per cent, lime 30 per cent and paris green 40 per cent may also be suggested as a possible white ant repellent. But all these mixtures and other methods are in the experimental stage and final results cannot be expected for some time.

Of the subsidiary measures mentioned above, planters are reminded that the termites which build mounds in which "queens" are commonly found are quite harmless to rubber trees. As queens of *C. curvignathus* (=*C. gestroi*) are rarely found and then only in timber, care should be exercised in accepting large numbers of so-called "queens" for compensation when gathered by members of the labour force. "Queen"-collecting will probably not have much practical value in the matter of keeping down the numbers of individuals. Richards discovered, moreover, that the removal of the queen was no guarantee that the colony would cease to exist, and his researches showed that substitution queens were provided by the ants to replace the parent queen. He says:

> Should the queen of a colony be killed, a number of substitutes are quickly provided to take up her duties. These substitution queens are easily recognisable from a normal queen by the fact that they have never developed wings. The wings of a normal-sexed individual are shed along a definite suture and the bases persist throughout life as small triangular stumps on the back of the thorax. The absence of these wing-stumps readily determines the substitution queens.

Flooding attacked areas has been mentioned above. This treatment is commonly used in areas of coconut palms attacked by white ants without any apparent damage being done. But flooded rubber areas, apart from paris green treatment, are very liable to suffer severe damage owing to the *Sphaerostilbe* root disease, and, in the writer's opinion, flooding should be strongly condemned. Selective removal of timber promises well, but unfortunately the identification of timbers which are sought out by white ants for constructing termitaria is very difficult for the practical planter.

For the period 1917–28 the white ant problem was not particularly serious because most of the plantations were mature. Now that large bud-grafted areas have been opened up, the position is different. Once undoubtedly successful results in the matter of high yields have been attained, there will be a fairly general move towards opening up new reserve areas, and replanting old areas on which latex yields are diminishing, so that in the future the problem is likely to be even

more serious. The present experimental programme on white ant control has been envisaged to meet forthcoming requirements.

Richards in 1917 argued strongly that clean clearing was the only sound method of combating attacks, especially in view of the fact that this would also help in the control of various root diseases which were becoming prominent at that time. In this view he is supported by Corbett in a recent publication, who declares that:

> it has been definitely established that the only satisfactory measure for eradicating white ants on both rubber and coconut estates consists in the destruction of all timber in which they can make their nests.

This statement is perfectly true, but the economic facts as to rubber plantations must be faced, and the "destruction of all timber", with the commodity at present-day prices, would prove ruinous. But the basic idea is sound, and taken into consideration together with the suggestions given for root disease treatment, there is not the slightest doubt that white ant damage on newly planted areas would be reduced to a minimum.

The most recent work on white ant control has been done by Beeley in Malaya. The following has been abstracted from an article recently published by him:

> Two common type of termites are often found on badly infected areas, one being *Coptotermes curvignathus*, Holmgr., the other being a species of *Capritermes*, probably *C. dolichocephalus*, O. John.
>
> The termite *C. curvignathus* appears to be the only offender which attacks the rubber tree. It is of common occurrence in low-lying soils and shows a strong preference for damp sheltered situations such as obtains under a heavy growth of cover crop.
>
> Though one must admit that an attack of root disease predisposes a tree to termite attack, nevertheless there is ample proof that *C. curvignathus* will attack apparently healthy young rubber trees and, if left undisturbed, can inflict fatal injury within three or four weeks' time.
>
> The seat of attack varies considerably and may be at a point a few inches above ground or at any point below ground-level. The most usual point of entry is at a fork of the tap-root or near some hollow malformation of the tap-root at about 9″ below soil-level. As the attack is extended upwards above ground-level a mud wall or casing is built round the trunk to protect the colony from other insects, birds and heat. Beneath this mud casing the bark is attacked almost at once at many points, causing exudation of latex which mixes and coagulates with the attached mud, forming a rubbery mass, which can only be cleaned off with some difficulty when treatment is undertaken.
>
> Once an entry is gained, the insects commence mining vigorously in the wood of the tap-root, causing numerous long, radially-flattened galleries.

These galleries are extensively interconnected and in time so weaken the tree that it is blown over by the slightest wind.

In the case of buddings being attacked by white ants the upper limits of the mud wall may not extend beyond the union, the attack being concentrated on the snag. In heavy cover, infested trees may easily be overlooked until too late, when the trees are usually blown down.

Various methods of control have been tried and the following list gives Beeley's opinion as to the probable order of merit.

(1) Opening up of roots and applying insecticidal dusts.
(2) Dibbling in around the bases of trees a small quantity of fumigant rubber jelly.
(3) Castor Bran placed in a shallow trench round all attacked trees.
(4) Using explosive gases to kill the termites by concussion.
(5) Digging to eliminate buried timber and nests.

It is pointed out that no method of treatment will quickly eradicate the termite pest and that a carefully planned campaign involving monthly inspection and treatment of affected areas must be carried out in order to effect a reasonable degree of freedom. It is not so much the type of insecticide used which is of importance but rather the thoroughness with which the job is performed.

Control of Termites in Young Rubber Trees using Insecticide Dusts.—In view of the promising results obtained in these experiments, the following method of control of termites by using insecticide dusts is tentatively suggested for use on estates whose managers would like to assist in obtaining further experimental data.

1. Mark out infested zones as indicated, Diagram XI, (*a*) supplies, (*b*) infested trees cut out and (*c*) present infested trees. Include also one ring of apparently healthy trees around the infested trees.

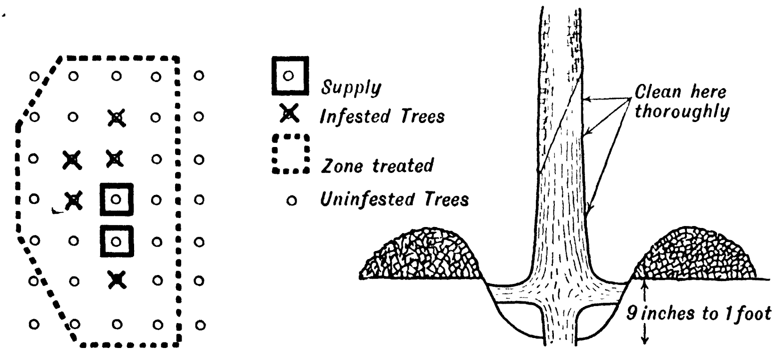


Diagram XI.

2. If white ants are observed to be entering the tap-root at a lower level, open up the roots, as shown in the sketch, to a depth of 9 inches or more. Clean the exposed bole of the tree thoroughly and blow on to the bark a light dusting of insecticide powder. Clean off all mud walls or debris from the trunk above ground and blow more powder into the mass

of mud and termites so collected and also lightly dust the cleaned trunk up to the height reached by the termites. About $\frac{1}{4}$ to $\frac{1}{2}$ oz. of dust is sufficient for one tree.

3. The crater at the base of the tree is left open for four to five weeks, when a further treatment with insecticide dust is given, after which the crater may be filled in.

4. Always attempt to trace up termite galleries to find and destroy nests.

5. In view of the fact that termites can destroy a four-year-old tree within four or five weeks of the original attack, it is recommended that a small gang of coolies should patrol infested fields, so as to execute a complete round of treatment every four weeks.

In heavily attacked fields having a flat peaty or alluvial soil it is advantageous to treat *all* trees in the area at the first round of treatment.

6. Suitable insecticide powders are as follows:

Sodium silicofluoride.
Calcium arsenate.
Cyanomag dust.
Paris green (with lime if used in wet peaty soils).

Suggested Method of controlling the Termite Pest of Young Rubber Trees by the Use of Fumigants.—As illustrated, demarcate infested zones as indicated (*a*) by supplies, (*b*) infested trees cut out and (*c*) present infested trees. Include also one ring of apparently healthy trees around the infested trees.

The tap-roots of all infested trees should then be opened up to a depth of nine inches and the tree thoroughly cleaned of mud. Four pieces of impregnated rubber jelly the size of a walnut are then placed round the bole at a depth of about six inches below the surface level. Fill in the hole with soil, so that the level of soil slopes away from the tree, as the fumes penetrate better through the dry soil than through wet.

Supplies and non-infested trees within the zone may have three or four similar pieces of impregnated rubber jelly dibbled in to a depth of six inches close around the tap-root.

Always attempt to trace up termite galleries to find and destroy nests.

As before, all known infested areas should be inspected once per month and fresh treatment given where necessary.

The following fumigant liquids are suitable for use in this way:

Orthodichlorbenzene.
Trichlorethylene.
Mixtures of the above two and carbon bisulphide.

The rubber jelly is made by treating small pieces of *dry* rubber clippings with the above fumigant liquids in the proportion of one pint of fluid to one pound of dry rubber. More of less fluid may be added according to the required viscosity of the jelly. The jelly should be kept in screw-capped vessels. It is advisable to keep records of trees treated, trees re-attacked after four and eight weeks or more, and costs of materials and labour used.

Control of the Termite Pest of Young Rubber Trees. Results obtained in

Routine Work on the Rubber Research Experiment Station, F.M.S.—In his *Report of Insect Pests in Ceylon* during 1929 Mr. F. P. Jepson, Department of Agriculture, Ceylon, suggested a method of using paris green in control of the termite pest of tea. After a little experimentation the method was adapted to rubber and was used to some extent on the Experiment Station. Perchloride of mercury was also used on a similar number of trees for purposes of comparison.

The method of treatment was the same as that which was recommended for estates, viz. that infested trees were opened up to a depth of nine inches, scraped clean of mud and latex and paris green powder lightly blown on to the roots and infested parts of the tree. The various fields were inspected periodically, usually at intervals of four to six months, and attacked trees duly treated. Observation, however, soon showed that it was possible for termites completely to kill a tree within four weeks of the commencement of attack. Trees were frequently not discovered until they were too far damaged to respond to treatment, so that the results summarised below under the heading "one treatment" are somewhat disappointing.

Treatment with perchloride of mercury consisted of opening up the roots in a similar way then spraying the trunk, roots and soil with one pint of a 2 per cent solution of the chemical or, better, 2 pints of a 1 per cent solution of the perchloride in water.

During 1932 the following results were obtained:

Degree of Control:

(1) *Paris Green*

(*a*) After one treatment	25%	deaths, nil
(*b*) After two treatments	70%	deaths, nil
(*c*) After three treatments	75%	deaths, nil

(2) *Perchloride of Mercury*

(*a*) After one treatment	32%	deaths, nil
(*b*) After two treatments	55%	deaths, 22%
(*c*) After three treatments	58%	deaths, 30%

The large death-rate during 1932 is due chiefly to the activity of root disease fungi (*Fomes*) in conjunction with the white ants. In many cases the trees were too far gone with both disease and termite attack and should have been dug out at once.

During 1933 paris green only was used until the end of September, when a change was made to Cyanomag on experimental grounds.

Degree of control with paris green, Jan.–Sept. 1933:

(*a*) After one treatment	42%	deaths, 5%
(*b*) After two treatments	63%	deaths, 25%
(*c*) After three treatments	66%	deaths, 32%

Omitting those trees which were obviously too weak to respond to treatment, it is found that the degree of control is as follows:

(a) After one treatment	50%	deaths, 2%
(b) After two treatments	75%	deaths, 13%
(c) After three treatments	78%	deaths, 20%

Reference to the root disease records shows, further, that several trees were given up as lost before the white ants began to attack them. If these trees are also omitted from the total it is found that the degree of control after three treatments, using paris green, becomes 84 per cent and deaths 14 per cent.

This indicates that paris green has given excellent results under ordinary routine estate conditions. With regular monthly rounds of inspection it is almost certain that much better results would have been obtained.

It should be noted that 25 per cent of the trees attacked by white ants had been for some time previously suffering from *Fomes* root disease. While admitting that attack by root disease fungi predisposes to attack by termites, observations show that the species *Coptotermes curvignathus* will attack well-grown, healthy trees of four or five years of age.

It should be kept in mind that the work detailed above was purely experimental, but the results obtained obviously justify further extensive application of the method to overcome, if possible, any objectionable features which may be met with in field practice. It may be held that one unfortunate episode should condemn the use of this chemical for white ant control, but the writer cannot subscribe to this view. The possibilities are obvious; if anything like a 70-75 per cent control can be realised, the white ant problem assumes proportions which need not cause any alarm to planters; in the meantime, however, it will be advisable to emphasise the need for expert advice before utilising paris green for the purpose indicated.

Sulphur Arsenic Mixture for Use in Universal Exterminator

The approved mixture is Arsenious oxide = (White Arsenic)—7 parts by weight.
Sulphur (finely divided) = 1 part by weight.

For the reaction to be complete, the charcoal in the brazier should contain sufficient red-hot charcoal to maintain the required temperature.

BORING BEETLES

Xyleborus parvulus, Eichh.

Boring beetles belong to the family *Scolytidae*, which is naturally divided into two groups, one of which comprises the "shot-hole" borers or "Ambrosia" beetles. Anyone familiar with the work of the "shot-hole" borer on rubber trees is aware that this is a very appropriate designation, for the effect resembles very closely that caused by firing small shot into wood. The galleries made by the shot-hole

borer are of a uniform width for their whole length and all burrows are made by the adult beetle; there are no galleries made by the larvae, as in a closely related family. The burrows are usually carried right into the heart wood. The larvae do not eat any wood; their food consists of fungi growing on the wall of the burrow; these so-called "Ambrosia" fungi are cultivated by the female beetles, which carry the spores in the stomach. Each species cultivates its own particular "Ambrosia" fungus irrespective of the kind of tree in which it is boring. The eggs are deposited in the burrows, and the presence of the beetles at work is revealed by the ejected wood-dust, which sometimes sticks together and projects from the entrance hole as a small funnel-like mass.

The genus *Xyleborus* comprises the majority of species which attack cultivated plants, and a large number of species of this genus have been found in dead *Hevea* stems. Green enumerated twenty-three species in 1914, but according to Petch the only two of importance on rubber are *Xyleborus perforans*, Woll., in Ceylon, and *Xyleborus parvulus*, Eichh., in Malaya. *Xyleborus morstatti*, Hag., in conjunction with the diplodia "die-back" fungus, causes a considerable amount of damage in coffee plantations in Java.

The males of the genus *Xyleborus* are unable to fly and in number and size they are greatly exceeded by the females. The boreholes made through the bark and into the wood are of small size, about one twenty-fifth of an inch in diameter. When the borers are actively at work the "frass" ejected from the holes often covers the exterior of the stem, and then the position appears somewhat alarming.

In Malaya serious borer attacks are never found on healthy, vigorous trees, but it has been demonstrated conclusively that slight bark-scraping, which exposes the outer cortical tissues, is quite sufficient to allow entry to the shot-hole borer. But the position is not as stated by Green, who considers that it is doubtful if any of these small beetles can penetrate the healthy bark of the rubber tree without being hopelessly involved in the viscid latex. Petch is inclined to the same opinion. If the bark of the rubber tree is scraped lightly so that there is no exudation of latex and a borer attack takes place on the exposed tissues, the insects bore through and, although there is a copious exudation of latex in which many of them are trapped, other individuals come along later and penetrate into the wood. The writer demonstrated this feature in 1916, and it appears that, as a result of light scraping, some external protective layer is removed. In Malaya leaf fires during the wintering season give the shot-hole borer the best opportunity of causing serious damage, for within four

to six days after the fire the scorched bark areas will be found riddled with the characteristic holes, in fact, shot-hole borer is nearly always prominent wherever the bark tissue of the rubber tree has been scorched from any cause. Serious damage also follows on lightning injury on mature trees, while trees suffering from the *Sphaerostilbe* root disease are also often severely attacked. In former years, when bark-scraping to obtain increased yields was practised in certain districts, severe attacks of boring beetles were recorded on the tapping panels. It is obvious, moreover, that borer attacks are likely to become prominent during a thinning-out period, when falling trees must necessarily come into contact with standing trees, bruising them severely and scraping away much of the external protective tissues.

Shot-hole Borer Attacks and Leaf Fires.—The description of the important features to be noted when leaf fires occur, together with treatment, is given in Chapter XVI. A short repetition is given here. The wintering period in Malaya is usually somewhat irregular, and it is the exception rather than the rule to find a thick carpet of dried leaves during any particular year. But if a long dry spell, without the intervention of occasional storms or showers of rain, is experienced during the wintering period, then a thick mat of dried leaves is formed on the ground, and this readily catches fire. Large areas may be damaged by fire under the conditions depicted, since within four to five days after the fire shot-hole borers will inevitably be at work, and suitable precautions must be undertaken. The entry of the insect is often followed by the appearance of the typical symptoms of *Ustulina zonata*, and between the insect and fungus the trees often succumb rapidly. It is not known whether the insects carry the *Ustulina* spores amongst the trees; the writer, however, has isolated this fungus from the bore-holes made by this insect. But once the wood is thoroughly attacked by the fungus small portions of diseased tissue are transferred as the insect progresses from diseased to healthy tissues and scores of centres of fungus infection are set up, and the tree may thus be rapidly killed.

Shot-hole Borer Attacks and Tissues scorched by Means other than Leaf Fires.—The close relation between scorched tissues and the presence of the die-back fungus *Diplodia* sp. has been commented upon in another chapter. Sun-scorch is the commonest form, and boring beetles often gain entry to the interior of mature trees through sun-scorched bark. The only remedy in this case is to excise any roots or branches which may be affected by the sun's heat.

Shot-hole Borer Attacks and Lightning Damage on Mature Trees.—The association of patch canker disease at the collar of mature rubber

trees which have suffered lightning damage has been fully discussed in Chapter XVI. As noted in the section on patch canker, affected bark evidently has a decided attraction for boring beetles. Treatment is as described, i.e. stripping out the diseased patches in large lumps; no scraping, other than to delimit the diseased area of bark, should be allowed.

Shot-hole Borer Attacks in connection with Root Attacks by Sphaerostilbe repens.—In this combination it is usually impossible to recommend any form of treatment, for the fungus disease is so far advanced that no hope can be entertained for the recovery of the attacked trees. The attacks of the insect undoubtedly hastens the death of the trees. The writer has seen sixteen acres of seventeen-year-old trees absolutely leafless and obviously approaching death which ten days previously were apparently healthy.

Shot-hole Borer Attacks and Bark-scraping.—About 1914–16 bark-scraping before opening the tapping panel was being practised by numerous estates; this procedure was based upon tapping results obtained by Fickendy, who reported an increased yield of 14 per cent. Shortly after this system of deep scraping was inaugurated the tapping panels showed symptoms very similar to those described for black stripe, and borers were penetrating through the diseased tissue into the interior of the affected trees. The only form of control was to cease scraping.

COCKCHAFER GRUBS

Psilopholis grandis, Cast.

The grubs of various species of cockchafers or May beetles have long been known to cause severe damage to various crops. In Queensland one species is considered to be the most dangerous pest to the sugar crop and the recommendations for control measures costs £8–£9 per acre per annum. Nowell, in 1915, reported that another species was occasionally destructive in Barbados canefields, and seemed confined to small and shifting areas, but in Mauritius, into which island it seems highly probable it was introduced in sugar-cane stools from Barbados, great and continuous damage is being caused over an ever-widening area. One or two species have been reported from Ceylon and Malaya as causing damage on young rubber plants, but an *en masse* attack on mature rubber areas had not been reported before 1930. Since that date two cases have come under the author's notice in Malaya.

The true cockchafer beetles fall into two sub-families, the *Rutelinae* and the *Melolonthinae*; the larvae of the latter are especially injurious

in the larval stage, being root-eaters. The true melolonthine grubs always rest with their curved body on the back or side (Fig. 59 *c*) and only move with much difficulty on the surface of the soil. The species referred to above are listed below:

On sugar-cane plantations in Queensland	*Lepidoderma albohirtum*, Waterh., and several other species.
On sugar-cane plantations in Barbados and Mauritius	*Phytalus smithii*, Arrow.
On young rubber in Ceylon . .	*Lepidiota pinguis*, Burm., and *Holotrichia leucophthalma*, Wied.
On young rubber in Malaya . .	*Tricholepis lactea?*
On mature rubber in Malaya .	*Psilopholis grandis*, Cast.

The cockchafer beetle under consideration has several synonyms as under:

Psilopholis grandis, Cast = *Tricholepis grandis* = *Holotrichia puberina* = *Lepidiota manilae.*

This beetle has been recorded from Sumatra, Java, Nias, Manila, Penang, Malacca and generally throughout the Federated Malay States.

Lepidiota pinguis, Burm., is a closely related beetle, the grubs of which have been recorded damaging young rubber roots in Ceylon, and *Lepidiota marginipennis*, Moser., the grubs of which were also damaging rubber roots, has been recorded from Borneo. In the latter case it is not clear whether or not the trees were mature. *Holotrichia leucophthalma*, Weid., another related beetle whose grubs have been recorded from Java, was again found damaging young rubber roots.

The cockchafer beetles in general are moderate-sized beetles with robust bodies, the elytra covering all but one spiracle, the legs only slightly broadened, and without horns or spines on head or prothorax. They are mostly dull-coloured insects, brown predominating in the coloration, and they vary in length from a quarter of an inch upwards. *P. grandis* is about $1\frac{1}{2}$ ins. in length and $\frac{1}{2}$–$\frac{3}{4}$ in. in breadth. The antennae are short, with the knob composed of one more joint in the male than in the female; the leaflets are also longer in the male; the prothorax is small, the elytra generally smooth and fitting tightly to the abdomen; the legs are moderately long, fitted for walking and to a less degree for digging.

The larvae of these beetles live in the soil and feed upon the roots of various plants. They are of a fleshy dingy-white colour, the body curved in an arch and the spiral segment large and smooth. There are many folds in the skin and three pairs of short-jointed legs. The larvae of *P. grandis* moves freely but slowly in the soil, but it is comparatively helpless on the surface, the curved body interfering with locomotion. When full-grown the grub makes a mud cell and transforms to a pupa in the soil (Figs 59 *a* and 59 *c*).

The imago flies by night; details with special reference to *P. grandis* will be given later. The fore-wings are not moved in flight; they are held rigidly and apparently serve for a parachute and as directors of flight. The food usually consists of vegetable matter leaves and flowers, and is eaten at night, the beetles hiding by day, but in the matter of food little is know of the habits of the adult insects in Malaya (Fig. 59 *a*).

Economic Importance.—Although not reported until July 1930, on one of the two heavily infested estates in Malaya, the grubs of the beetle have probably been present for at least five years (1928). No suspicion arose until the grubs were found in the soil in enormous numbers, and it is almost certain they had been present two or three years before the date of report. On one estate an attempt was made to improve the position by continuous digging and hand collection of the grubs. This field of rubber was 96 acres in extent and the trees were thirteen years of age. The grubs were ultimately found to be generally distributed throughout the whole of this field, but large numbers were found over an area of 50 acres, and the worst affected area was about 25–30 acres; the latter was dug over thirteen times.

In May 1931 the following were collected in one day by 57 coolies: 24,200 small grubs, 20 large grubs and 145 beetles. Even when such large numbers were obtained by hand-collecting the number of grubs did not perceptibly diminish, and in view of the risk of injury to roots which might influence the grubs to invade them, a recommendation was made to stop digging. This particular area carried only a light undergrowth, and the ground was slightly undulating, being bounded on three sides by virgin jungle. The grubs are still confined to this particular field, neighbouring fields being still free on the date last examined (December 1933).

The other badly infested area occurs on an estate situated in the foothills of the main range, and is bounded along its whole length by virgin jungle. The rubber trees on this estate have not been tapped for a period of years, and the land is hilly. In order to prevent soil-wash on the hilly slopes, a natural heavy undergrowth has been

successfully established. The first indications of the presence of the grubs was on a steep hill-slope adjacent to the jungle, over an area of about one acre. In this area the undergrowth showed signs of dying off in patches and the soil appeared to be very spongy when walked over. The manager first suspected the presence of an oil spring until a strong wind passed over the estate, and the whole of the undergrowth was laid low. An examination over the spongy area showed that the roots of the various species of plants comprising the undergrowth had been eaten away, and slight disturbance of soil by digging soon revealed the typical cockchafer grubs. In such hilly estates, where the undergrowth must be encouraged to prevent soil erosion, much damage can be done by a massed attack, for the time taken to re-establish a good natural undergrowth is some two years or more, and much top-soil will necessarily be lost during this period.

When the grub infestation was first brought to the writer's notice statements were made that a large reduction in the yield of rubber, amounting to 50 per cent, had been occasioned and that the latex was watery, i.e. had a low D.R.C. (Dry Rubber Content). This may very well have been the case, but when comparative D.R.C. tests were made in February 1932, on latex taken from affected and unaffected fields, the D.R.C. of the latex from the infested field was shown to be normal at 3 lbs. $10\frac{1}{4}$ ozs. to the gallon; two unaffected fields showed 3 lbs. $10\frac{1}{8}$ ozs. and 3 lbs. $9\frac{5}{8}$ ozs. per gallon respectively. With regard to yields in pounds per acre per annum no exact figures have been obtained as yet (September 1933), but it may be possible to obtain figures at a later date. In the writer's opinion the yield of latex and rubber appears normal for the type of soil, and it is doubtful if any serious loss of yield has ever been experienced.

A rough estimate of the amount of root damage done was made. The root systems of fifty-two trees growing in the worst infected area were exposed and it was found that seventeen had suffered root damage and thirty-five showed no signs of attack. But it has to be remembered that the soil of this area was dug over repeatedly and some root damage from this cause would be inevitable; further, various soil fumigants had been tried over the area, so it is difficult to apportion the damage correctly. The inference, of course, is that all the root damage cannot be attributed to the grub infestation.

At the present time it is quite obvious that the tap-roots of young rubber seedlings are eaten through just below the surface of the soil, and that they form excellent food for the grubs. It seems probable that if the grubs cause damage to mature trees the portions likely to be attacked would be the small absorbing rootlets. As mentioned in

preceding sections, the repair mechanism in the root system of *H. brasiliensis* is extremely efficient, and any damage done by the grubs to small rootlets would be quickly repaired by the outgrowth of adventitious rootlets. It is, therefore, not reasonable to expect a big diminution in yield because of a massed infestation of the soil by the grubs of cockchafer beetles, but it would be quite impossible to prevent annihilation of the plants if a nursery bed of rubber seedlings became seriously infested.

The grubs are practically polyphagous; all plants in a mixed undergrowth are eaten indiscriminately. The wild fern, *Gleichenia linearis*, is a favourite food plant but nothing seems to come amiss; on one occasion grubs were found working through a neglected pineapple bed, and even the root systems of such a hardy plant were eaten clean away, and all the plants were leaning over at an angle. Of the usual cover crops, it has been shown that grubs will readily devour the roots of *Mikania scandens*, but slight feeding only was observed on the roots of *Indigofera endecaphylla* and *Tephrosia candida*, and no feeding took place on *Crotalaria anagyroides*. At the present time it seems advisable to encourage the development of alternative food plants on which the grubs might prefer to feed and also to increase a fallen-leaf cover over the soil.

Grubs are found in the jungle and appear to be slightly nearer the surface than in the infested areas.

Little is known regarding the host plants of the adult beetle *P. grandis* in Malaya. It has been established that they will not feed on leaves of *H. brasiliensis* or *Mikania scandens*. They will feed on Mango, Mangosteen and Jambu (*Eugenia* sp.) leaves.

Life Cycle.—Detailed entomological observations on the life cycle of the insect in Malaya have not been made, but from the available data it appears that the life cycle is normal and agrees essentially with the details of related cockchafer beetles reported from other countries. The life cycle is completed in twelve months. The eggs are deposited during March and pupation begins in January. Adult beetles occur from January to April. The duration of life of the adult beetle under natural conditions is not known exactly but it seems likely that it is not less than three or four weeks.

LIFE HISTORY.—The eggs are white, ellipsoid bodies and are laid in the soil at a depth of one foot below the surface. They are deposited in clusters of 11-34 ova (Fig. 59 *a*).

LARVAE.—On a visit made in the middle of March 1932, only one or two large grubs could be found. A number of very small grubs, however, were obtained, and as they are invariably found in small

colonies it indicates that the grubs soon separate after hatching from the eggs. The grubs are for the most part confined to the first nine inches of soil but go deeper when the ground has been disturbed, occasionally to a depth of two feet. They are to be found in the soil during the whole of the year, but a decrease in numbers of full-grown grubs begins to occur in December and most pupae are found about the end of January (Figs. 59 *a* and 59 *c*).

PUPAE.—On the same date (*supra*) pupae were found every day by the digging coolies, but the numbers were diminishing daily.

IMAGO.—During the same visit adult beetles were found in the soil in large numbers. When the beetles first emerge from the pupal stage the wing-cases are soft and it seems probable that the beetles remain in the soil until the cases become hardened. One hundred beetles found in the soil on March 2nd 1932, were examined on that date and 33 per cent were found to have soft wing-cases; on March 14th the proportion of "soft" beetles was much smaller. The following approximates to the general life cycle in Malaya: Egg stage, 14 days. Larval stage, 311 days. Inactive larval stage, 7 days. Pupal stage, 22 days. Inactive beetle stage, 11 days. One generation occurs in the year but there is considerable overlapping in the various stages.

Normally no beetles are seen above ground during the daytime, but a few may rest on the under-side of the leaves of rubber trees and other shrubs. A report from Queensland states that several species of *Ficus* are favourite resting-places of the adult beetle *Lepidoderma albohirtum*, and it is recommended that groups of *F. pilosa*, Reinw. *ex* Blume, and *F. benjamina*, Linn., should be planted in the sugar-cane areas and that the beetles can be collected from them by shaking, which causes them to fall to the ground. As far as our observations have gone in Malaya, the great majority of the adult beetles spend the day underground.

In the evening a very few beetles are active before 6.45–6.50 P.M. They must emerge from the ground and take wing immediately as none were seen crawling on the ground before 6.45 P.M., yet a few minutes later they were in full flight everywhere and the powerful droning noise can only be likened to that produced by a powerful fleet of aeroplanes overhead. The flight is very swift and, as far as could be judged in the darkness, not very high. Many beetles flew quite low and sometimes described circles over a small area. It is not known when the evening flight ceases.

At 5.40 A.M. the field is quite silent and in total darkness. At a minute or so before 6 A.M. the beetles appear suddenly and there is a strong flight for a period of about twelve minutes. The number of

beetles in flight, however, is probably only a quarter of that of the evening flight, and the insects are not so strong on the wing and possibly fly lower. By 6.15 A.M. the flight is over and the beetles fly (not drop) to the site of landing. On one day when observations were being made two or three beetles were seen to crawl under the nearest dead leaf and remain there. Another beetle crawled under a leaf and burrowed and it was not successfully recovered. Another beetle crawled into a hole in the soil at the base of a stump when it was seized by a scorpion. The four or five beetles of the morning flight which it was possible to examine proved to be males, and appeared to be in a state of exhaustion.

The length of flight of the beetles, as determined by painting 600 beetles, indicates that although they are strong on the wing the circular movement employed during the flight prevents them moving to any great distance, half a mile perhaps would be the limit when flying among trees. No beetles have been found in copulation, but there is evidence which suggests this takes place during the evening flight.

The food of the adult beetle is not definitely known. It seems as though it does not consist of rubber leaves or leaves from the neighbouring jungle, and the only conclusion which can be drawn at present is that it must be obtained from the soil.

Biological Control by Natural Agencies.—It is a well-known fact that cockchafer beetles are parasitised by various species of Scoliidae or "digger-wasps", and, in other countries, by an entomogenous fungus commonly named the "green muscardine" fungus (=*Metarrhizium anisoplioe*). Up to date, specimens of white grubs attacked by this fungus have not been found in Malaya.

(*a*) SCOLIID WASPS.—A wasp, *Scolia manilae*, was introduced into Hawaii in 1915 and 1916 to aid in the control of a grub attack on sugar-cane. This was successful, for the beetle (*Anomala orientalis*, Walent.) is now fully controlled by the wasp parasite.

Two digger-wasp parasites of the grubs of *P. grandis* have been obtained in Malaya. These are *Campsomeris pulchrivestita*, Cam., and *Campsomeris tristis*, Sauss. (=*C. javana*, Lep., or *C. iris*) (Fig. 59 *a*). On December 22nd both parasites were very conspicuous in the field, and on April 9th following there was no apparent decrease in the numbers of either species.

Under normal conditions the wasp parasites have to burrow several inches below soil-level before reaching a suitable host, and several writers refer to a remarkable instinct the females possess for locating their victims. This has not been confirmed in our experience

with *P. grandis*; numerous wasps have been followed into the soil with a trowel, but in no instance was a grub found, which suggests that the female enters the ground hoping to find a grub on which to oviposit and not because she knows that there is a grub underground.

It will be of great interest to non-technical readers to have an account of the tactics adopted by the female wasp parasites when overpowering the grubs underground. This account is given by Illingworth:

> The wasp warily approaches the powerful jaws of its intended victim by clinging to its body and crawling with erratic movements until encountering the legs of the alarmed grub, which, evidently aware of the impending danger, keeps squirming and pawing the air, threatening its enemy at the same time with widely opened mandibles.
>
> A few seconds are passed in this preliminary fencing, and then the wasp, making a sudden dive forward, seizes with caliper-shaped jaws one of the mandibles of the grub, and without loss of time drives its paralysing sting deeply into the throat of the unfortunate creature. The effect is almost instantaneous, the rigid convulsive body becomes limp and unable to offer further resistance, as the parasite, now withdrawing its sting, plunges it deliberately several times into the mouth of its victim, between the maxillae, in order, presumably, to paralyse the mandibles.
>
> Sometimes, however, the tables are turned, and the venturesome parasite is seized and fatally crushed in the sharp jaws of its adversary, in which case it appears that the victorious grub does not rest until it has cut the wasp into little pieces.

The digger-wasps may attack grubs working on or near the surface, and it has been observed that when this is done the wasps begin to dig the soil away in order to bury the body of the grub underground. This can be done in the relatively short period of twenty minutes.

Pendlebury reports that *C. javana* was the dominant species in the Malayan outbreak. Under laboratory conditions the female wasp attacks and stings the grub with vigour, which rapidly becomes quiescent and paralysed. She then turns her prey on its back and appears to use her sting as a brush, and smears the ventral surface of the grub with it preparatory to oviposition. The egg is dropped on to one of the ventral somites, generally the fourth, though any one from the first to the fifth may be chosen, the position depending on which way the wasp was facing during the act of oviposition. The egg usually assumes an erect posture (Fig. 59 *b*).

The egg stage lasts from two to three days, when the wasp grub hatches and commences to feed upon the beetle grub. The wasp grub continues to feed from five to six days before pupating; the pupal

stage lasts from twenty-seven to twenty-nine days in the male, and from thirty to thirty-two days in the female.

It has been found that, in the field, the wasp will not oviposit on other than nearly full-grown grubs.

As regards *C. pulchrivestita* the laboratory conditions have not appeared to favour its development. The mode of attack is similar to that described above. Though the fourth somite of the beetle grubs is the one usually chosen by the wasp for oviposition, any segment from the first to the seventh may be selected. The egg stage has been found to last three days, and the grub stage seven to eight days; the pupal stage in one case was forty-two days.

As will be seen from Fig. 59 *a*, the male and female of these wasps species differ considerably in size and coloration, i.e. exhibit sexual dimorphism. The females are considerably larger than the males. Much confusion has arisen because of this sexual dimorphism, for the male and female of the same species have often been named as separate and distinct species.

On a visit made last year males of *C. javana* constituted at least 75 per cent of the total, females of both species being very little in evidence. Between 8 A.M. and 2 P.M. two or three females of *C. javana* may be seen each day and these are invariably being pursued by numbers of male wasps. Between 7 A.M. and 8 A.M., however, females are much more abundant and occur in about equal numbers with the males. The explanation appears to be that both sexes occur in approximately equal numbers, but the females spend almost the whole time underground.

Male wasps of both the above-mentioned species were found feeding on the flowers of a shrubby jungle plant—*Urophyllum streptopodium*, Wall. (Rubiacea); only three plants of this species were found and all were constantly visited by male wasps.

A Bombylid fly, *Hyperalonia tantalus*, F., acted as a hyper-parasite and attacked several of the wasp grubs or pupae, but they did not occur in such quantities as to be a noticeable check. Other species of this family have been recorded as parasitic on mud-wasp grubs, or even mason bees.

A composite illustration is given, Fig. 59 *a*, which shows characteristics of eggs, larvae or grubs, pupae and adults of *P. grandis*; male and females of *C. Iris* (=*javanica*) and *C. pulchrivestita*; and pupae and adult of *Hyperalonia tantalus*.

(*b*) METARRHIZIUM ANISOPLIOE (METSCH.), SOR.—The entomogenous fungi are comprised in one genus, i.e. *Cordyceps*, and most of the individual species attack insects and only form perfect

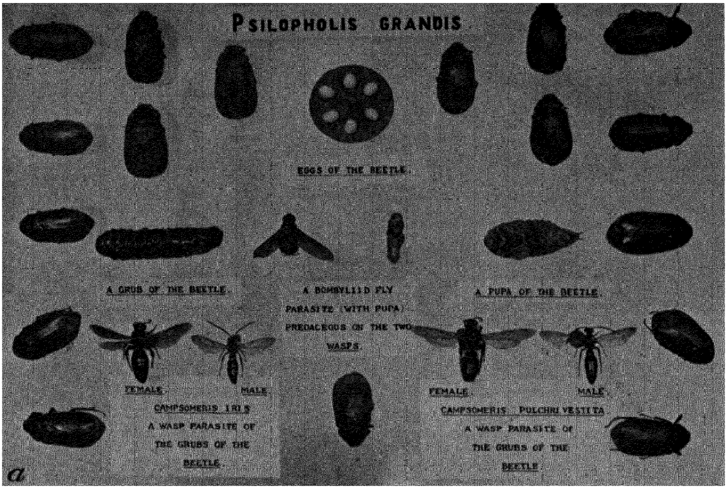


FIG. 59 *a*. Photograph of composite group of eggs, larvae (white grubs), pupae, and adult beetles of ***Psilopholis grandis***, together with male and female specimens of "digger wasps", *C. Iris* (*Javana*) and *C. pulchrivestita*, which are parasitic on the "white grubs". Also specimens of Bombylid fly (*Hyperalonia tantalus*) and pupae thereof; this insect is predaceous on the two wasp species. (Set up by the Entomological section, Dept. of Agriculture, S.S. & F.M.S., under the direction of the Govt. Entomologist, Mr. G. H. Corbett, B.Sc.)

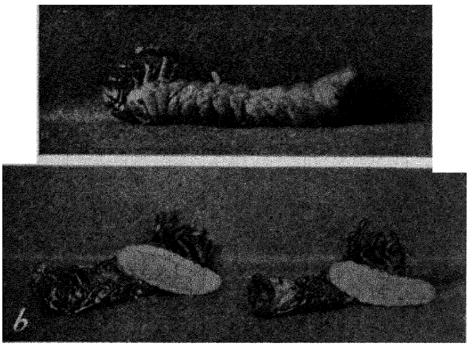
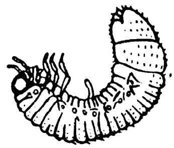
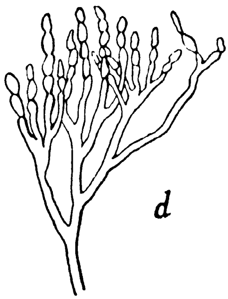


FIG. 59 *b*.—Showing white grub, with egg of digger wasp in the most usual position, standing vertically. Below, the illustration shows the developing larvae of the wasps feeding on the body of the white grub. (After Dammermann.)



c

FIG. 59 *c*.—Showing natural, curved position of white grub in soil.



d

FIG. 59 *d*.—Showing chains of spores, as formed by the "green muscardine"

fructifications on substrates rich in proteins. Gaumann says the genus includes about 200 species, but Gwynne, Vaughan and Barnes record that the group includes only about 60 species, which are mainly tropical parasites on insects, the bodies of which become transformed into sclerotia.

As explained in a preliminary section, many fungi form two types of fructifications, the perfect and the imperfect, and that there is a vast group of fungi in which only imperfect fructifications are found. The fungus that will be dealt with in the present case falls in the latter class of *Fungi imperfecti*. According to Gaumann, the types of fructifications, as they appear on infected insects, are called "Muscardine", which name is transferred to the disease itself. With sufficient nourishment the spore-bearing filaments coalesce into graceful white or bright-coloured tufts (coremia) and they are classed in the imperfect genus *Isaria*. *Metarrhizium* is a fungus belonging to the genus *Isaria* and the two names are often used interchangeably. This explanation may clear up the position, and as the fungus under consideration produces bright-green tufts of spores, it is commonly known as the "green muscardine" fungus.

Metarrhizium anisoploae (Metsch.), Sor., has attracted much attention, and attempts have been made both in the West Indies and in Queensland, and probably other cane-growing countries, artificially to develop the fungus on a large scale with a view to its employment as an aid to natural control.

The "green muscardine" fungus forms chains of spores (Fig. 59 *d*) in a very similar manner to the ordinary green *Penicillium* fungi; the latter become prominent on many domestic articles which are allowed to remain in damp situations; in fact, they can be considered related fungi.

This fungus is not only of interest as destroying melolonthid grubs on sugar-cane in Queensland and other sugar-cane-growing countries. It has always been considered to be of great practical interest, as it has long been recognised as a most important natural enemy of *Tomaspis saccharina*, which is the well-known Frog-hopper pest of sugar-cane in the W. Indies. At times fairly favourable reports have been issued following on the artificial propagation and scattering of the spores over infested cane-fields, but the general opinion has been that artificial spreading of fungus spores is not followed by results which are proportionate to the expense and labour involved. A recent report by Pickles indicates, however, that the fungus *M. anisoploae* must still be regarded as an important factor in natural control of Frog-hopper.

The appearance of the melolonthid grubs infected with this fungus is typical, for the body, instead of decomposing after death, retains its shape and, gradually hardening, turns at first whitish, and finally dull green owing to the production of the green spores. The internal organs and fluids of the victim are quickly absorbed, and replaced by vegetable tissue constituting the mycelium of the fungus, until, in the case of grubs of *Lepidoderma albohirtum*, in Queensland, the entire grub becomes as firm as a piece of hard cheese and can be easily broken to pieces. These hardened grub-cases filled with fungus hyphae are known as sclerotia.

It seems obvious, from the point of view of control, that grubs parasitised by the fungus would be usefully employed. Such parasitised grubs should either be left in the ground or broken into powder which can be mixed with the soil.

Some Observations on control of Psilopholis grandis in Malaya.—When making recommendations for the control of plant pests and diseases it must be remembered that the position is definitely governed by the economics of the situation. In Queensland, control of melolonthid grubs in sugar-cane fields is now established by injecting into the soil either carbon bisulphide (CS_2) or paradichlorbenzene. This method of control costs £8-£9 per acre for each crop of treated cane. The position is such, however, that the sugar farmer gets a valuable return for his expenditure and labour, and from the economic view-point, the balance is not overloaded on one side or the other.

The position in Malayan rubber plantations is exactly the opposite. No large losses of crop have been reported; there is little damage done to the trees; the pest is confined to two areas covering about 100 acres each, and in one of these areas has not spread from the infected into neighbouring fields. Any control method which disturbs the soil cannot be recommended, because such disturbance makes the grubs burrow more deeply, and the soil cannot be mechanically furrowed by plough. With furrows produced by the plough it is comparatively easy to obtain good results from lethal gas injection. Thus for the present the only method that can be considered is to encourage natural control, more especially in the direction of increasing the number of predatory wasps. If simple and cheap methods were available to prevent the adult female beetle from ovipositing, these would be of great use in expediting control. As it has not been mentioned above it would be advisable to draw the attention of readers to parthenogenesis (viz. the laying of eggs by the female wasps without copulation). This has been proved to be a

common occurrence in the "digger-wasp" family, and the larvae which develop from these eggs pass through a normal life history.

Some of the restrictions in respect of control imposed by the particular conditions existing in mature rubber plantations have been mentioned above; (*a*) soil disturbance of any description drives the grubs to burrow more deeply; (*b*) lethal gas injection cannot be recommended when the distribution of the grubs is widely diffused. Other restrictions are: (*c*) the grubs do not appear to be parasitised by the Scoliid wasps before they are three-quarters grown, so they have a considerable period during which they may cause damage; (*d*) possible alternative food crops which will grow under shade have not yet been found.

Poisoning the soil with sodium arsenite, paris green and lead arsenate has proved unsuccessful. Scent traps set up with eight different mixtures were useless, for after eight days only nine beetles were caught and these probably hit the traps by accident. Light traps were useless with *Psilopholis grandis* for the beetle actively avoided the light, though in Queensland it is reported that *Lepidiota albohirtum* is definitely attracted by this means. Pits filled with rich jungle soil or fresh bullock dung proved useless, as also did darkened boxes. While many birds would undoubtedly devour the grub if available and also the beetles, bird life is not unduly prominent round the infected areas in Malaya.

Wild pigs visit the infested areas nightly and eat any beetles which are on the ground. They have not actually been seen eating the grubs, but, during the grub stage, wild pigs return night after night to the areas where the grubs are at work, and if a search is made, grubs can always be found in the soil areas disturbed by the pigs. It is highly probable, therefore, that wild pigs make an active search for the grubs during the hours of darkness.

If wild pigs therefore are present in the vicinity they should be encouraged and all pig-shooting stopped. The domestic pig is useless, for while they will eat the beetles if fed to them during the day they pay little attention to them at night.

It is stated by authorities in Queensland that the adult beetles prefer to rest during the day on various *Ficus* species, such as *F. pilosa* and *F. benjamina*. The latter species grows well in Malaya, and clumps of these trees should be introduced into the infested areas.

Further search is required into the feeding habits of the Scoliid predators in order to discover the jungle plants on which they feed. When found, the chosen plants should be spread around and about the areas where the chafer grubs are working in the soil.

As far as our experience in Malaya will allow us to judge, the collection of grubs by digging, or of the adult beetles by nets, offers no hope of success.

Geometrid Moth

Hemithea costipunctata, Moore

This Geometrid moth was found in 1920 feeding on the inflorescences of the rubber tree and was reported upon by Corbett and Ponniah in 1922. The eggs are laid usually singly, but occasionally in twos or threes one above the other on the flowers and stalks of the inflorescence. They hatch out in two to four days.

The larva, emerging from the egg, is greenish in colour with three distinct lines running longitudinally along the body. It possesses three pairs of thoracic legs with only one pair of abdominal feet, placed on the ninth segment in addition to the anal pair, or claspers. The larva progresses by moving these two pairs of feet up to the thoracic legs so that the body is thrown into a large loop and they are hence called "loopers" or "geometers". The caterpillars generally rest during the daytime, reposing at an angle from the inflorescence by clasping a pedicel of a flower. In this position they look like the stalk of a rubber flower. The colour, resembling that of the environment, and the attitude of the larva when at rest, prevent it being readily detected and account presumably for this caterpillar not being observed before 1920. When full-grown the caterpillar is about 1 inch in length and attains this condition in seventeen to twenty-five days.

The pupae are seen suspended by their anal ends among the inflorescences. They are about ½ inch in length; the general colour at first is pale green, but later this changes to dark green with blackish spots.

The moth emerges from the pupa in from eight to eleven days. It has a wing expanse of about ¾ inch, the upper surface of the wing being cobalt green in colour with three white, silvery wavy lines. The under surface of the wings is silvery green in colour. The moth lays eggs four to five days after emergence from the pupae.

The life cycle occupies from twenty-eight to thirty-two days.

The diseased branches and blossoms were first found on rubber trees nearly six years old. The insect hitherto has apparently only attacked the lowest branches, starting at the blossom and gradually working down to the branch, leaving a blackish discoloration. The leaves curl up, discolour slightly and eventually drop off. As the caterpillars feed almost wholly on the inflorescences, the leaf effects are

probably the result of some reaction due to the mechanical injury caused by caterpillars eating the flowers.

Corbett and Ponniah, in conclusion, state that this pest is, at present, of no serious importance, but if seeds are required commercially for the extraction of oil further observations as to its habits and control will be necessary.

Attention may be directed here to the suggestion made in a previous section with regard to the possible reaction to attacks of *Oidium heveae* (page 299) and to squirrel damage (page 299). A similar after-effect may develop if attacks by this moth on the inflorescences result in a diminution of the seed supply.

Limacodid Moth

Thosea sinensis, Walk.

Fig. 60 illustrates the caterpillar of this insect, on which some remarks have already been made. In a recent outbreak, where it ap-

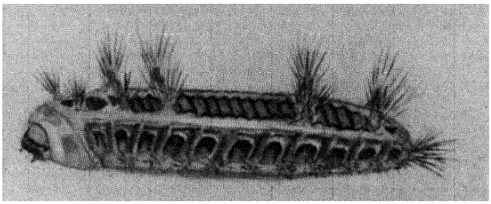


Fig. 60.—Caterpillar of *Thosea sinensis*. × 2.

peared in a block of seventy acres of old rubber, the caterpillars were found definitely eating the leaves of young rubber seedlings. The area was under a cover of controlled grass and, in parts, *Mikania scandens*, and it was supplied with rubber seedlings twelve months before the outbreak. The caterpillar appears first to attack the grass, which was entirely eaten off in places. The rubber seedlings are next attacked, the caterpillar devouring the leaves. They were also found clustered on the tapping panels of the old trees, but visible signs of damage were not apparent in this position. This insect must now be included in the list of those which have been found causing direct damage on rubber plants. Its real significance is, of course, the indirect damage aforementioned.

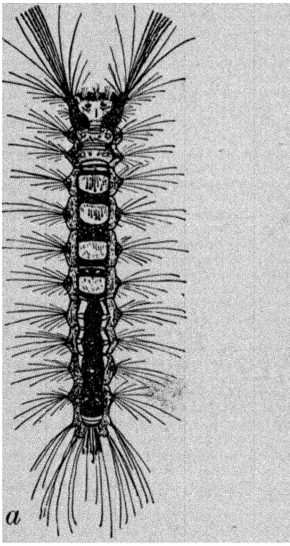
In the attacks recorded, the caterpillars practically disappeared

after one month, but a further attack soon appeared, but in a lesser degree, and this again subsided. At a later date the caterpillars appeared again but in much smaller numbers and were confined to one portion of the area originally infected.

Lymantrid Moth

Orygia turbata, Butler

Orygia turbata, Butler, is a Lymantrid moth which normally pursues its life history in cover crops which are sown for the purpose



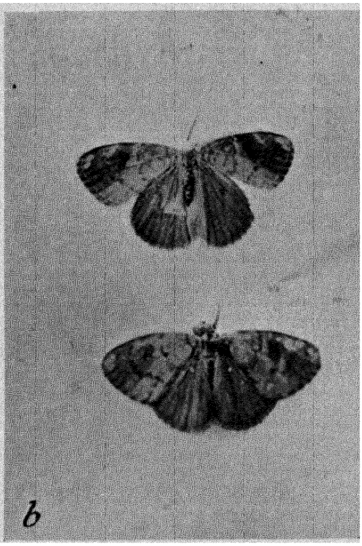


Fig. 61 *a*.—Caterpillar of *O. turbata*. × 2¼.

Fig. 61 *b*.—Winged Males of *O. turbata*. (Natural size.)

of ground shade and prevention of soil movement. A few reports have been made of the insect migrating from cover crops to rubber trees, where slight damage is done to the tender cortical tissues opened up by the tapping operation; small wounds are made which later come to resemble tapping wounds. In the majority of cases the caterpillars (Fig. 61 *a*) have been found on young or seedling rubber trees on the leaves of which egg masses have been laid, but Fig. 61 *c* shows a caterpillar at work on the tapping panel. While the damage done has never been serious, insect migrations from one crop to another must always be carefully considered from the entomological

point of view, for there are numerous cases of very serious losses resulting from an insect gradually becoming attuned to feed and develop on a new plant very distinct from that on which it formerly lived.

This insect shows a marked preference for *Mimosa pudica*, L., and also *Centrosema plumieri*, Benth. The latter is one of the most favoured cover crops grown on Malayan rubber plantations.

The first outbreak of *O. turbata* in Malaya was recorded in 1926. The caterpillars originated in "belukar" bordering the estate at a certain point, spreading from there to the cover crop, *C. plumieri*,

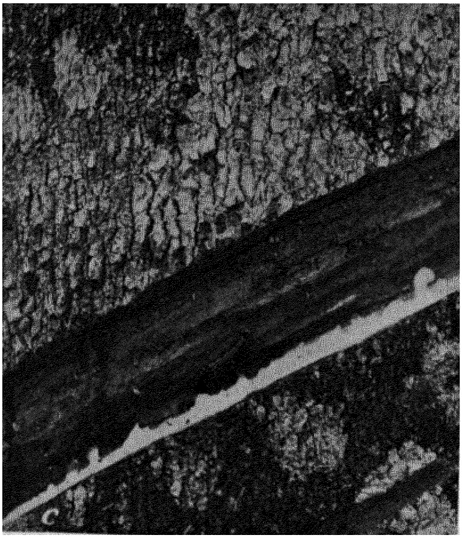


Fig. 61 c.—Caterpillar of *O. turbata* on tapping panel of *Hevea*. Note similarity of coloration.

which they ate over a very large area; they also attacked the leaves of the rubber plants to some extent. As the migration of this moth is entirely dependent on the caterpillars (the females being wingless), it was advised that a poison barrier should be sprayed for a depth of about three yards beyond the limit of the last advance of the larva, and that all the stages of the insect found inside the area already attacked should be collected. These measures proved distinctly successful. In this outbreak *O. turbata* confined itself entirely to the *Centrosema* cover, *Passiflora* and *Calapogonium* being untouched; another outbreak was reported where rubber seedlings in a clearing

of about 260 acres were found to be badly damaged by swarming caterpillars. These had apparently spread from the weeds surrounding the area. The larvae, in this case, were polyphagous, feeding on *Mimosa* sp., *Crotalaria* sp., *Melastoma* sp., and other plants.

These early recorded outbreaks of *O. turbata* occurred on seedlings and young rubber plants, from which the various stages of this insect were easily collected and destroyed. The position might have been different if the caterpillars had migrated to mature trees, for in such cases control measures would have been considerably more difficult. It is possible also that the caterpillars might have become more definitely associated with older trees. Since 1930 the larvae of *O. turbata* have been sent in each year from various estates.

This insect appears chiefly to use the rubber plants for the purpose of pupating. It seems to be characteristic of the species that when fully fed the caterpillars move away from the original host plant, i.e. *Mimosa* sp., a distance of some six to ten feet to a taller plant on which to form the cocoons. These are usually spun in small groups, three to seven in number, on the under-side of rubber leaves, the three leaflets sometimes being bound together and the edges curled in, so that the group of cocoons becomes enclosed in a very open, irregular network of silk. Almost invariably the groups of cocoons contain both males and females; the male chrysalids are much smaller than the females and are easily distinguishable.

Only the males fly (Fig. 61 *b*), the female being wingless and rarely moving more than one inch away from the original network. Usually they remain practically stationary after emergence. The eggs are laid in a mass, one layer deep, upon, or in close proximity to, the cocoon from which the female has emerged. Successive broods rarely appear more than ten feet away from the preceding one. This fact means that the spread in area is slow and is a point in favour of obtaining control reasonably quickly. Each mass generally contains from 250 to 300 eggs, but masses have been counted containing as many as 450 eggs. They are laid in regular rows, each egg being covered with short yellowish-coloured hairs. Each egg is about 0·75 mm. in diameter, reticulated, the top slightly flattened and depressed. The centre of the depression is greenish-yellow in colour.

The caterpillar of *O. turbata* (Fig. 61 *a*) is blackish in colour with long branched hairs arising from various parts of the body, especially the sides. Just behind the head there are two tubercles which are usually red at the base, except in the last instar, from which pencils of long black hairs arise. The thoracic segments are marked with white.

The first four segments of the abdomen bear tufts of hairs, which in the male caterpillar are generally yellow in colour, though the first two tufts are often black during the fourth instar of the female larvae. The fifth and sixth abdominal segments have white markings in the middle in the early stages and broad white lines near the sides in the later stages.

The sixth and seventh segments have red tubercules in the middle which are known as *eversible* glands. Most of the caterpillars conform to this general description, except for differences in size and slight variation in colour.

If more detailed observations on the coloration of the various instars is required, the reader should consult the article by Corbett and Dover.

The life cycle is completed in about one month. The male moth has a wing spread of about one inch and is coloured a rusty brown; as mentioned above, the females are wingless.

For control, Corbett and Dover recommend a poison barrier of lead arsenate as a means of confining the caterpillars to the area already occupied by them, as the insects can only spread by movements of the caterpillars. Lead arsenate (1 lb. to 50 gallons of water) is sprayed on the leaves of *Hevea* and on any cover plants at the limits of the area infected with the caterpillars. If the cocoons and egg masses and caterpillars are to be found in profusion on young rubber plants, hand picking will help considerably towards a quick reduction.

Caterpillar and Noctuiid Moth

Spodoptera Sp. and *Tiracola plagiata*, Walk.

In 1918 Richards recorded a swarm of caterpillars in Malaya which devoured all the available grass and weeds and then attacked young rubber plants, stripping the leaves and eating the young green bark, over an area of several acres. This caterpillar was reported to be a species of *Spodoptera*.

Another example of insects migrating from cover crops to rubber, is provided by the Noctuiid moth *Tiracola plagiata*, Walk., a major pest of the castor-oil plant in Malaya. An outbreak of caterpillars of this species occurred on castor-oil plants in 1923, causing considerable damage to the crop, from which they spread to rubber plants of about eighteen months old. Serious damage was done, and practically all the rubber plants were defoliated. The caterpillars of *T. plagiata* would seem to be strongly possessed with the migratory instinct, for on several occasions they have caused damage to rubber plants.

Psychid Moth

Psyche (*Acanthopsyche*) *snelleni*, Heyl.

The larvae of one or more species of psychid moths occasionally appear in large numbers and begin to feed on the recently renewed bark in close proximity to the tapping cut, making small wounds from which latex exudes. The larvae are enclosed in cases derived from old vegetable material such as dead leaves, and are better known as "case-moths". The cylindrical larval case of *Psyche* (*Acanthopsyche*) *snelleni* is about 1¼ ins. in length and has been found on *Hevea* trunks in Malaya on several occasions; it is also a well-known pest of tea in Java.

The female moth is wingless, so that it is during the comparatively

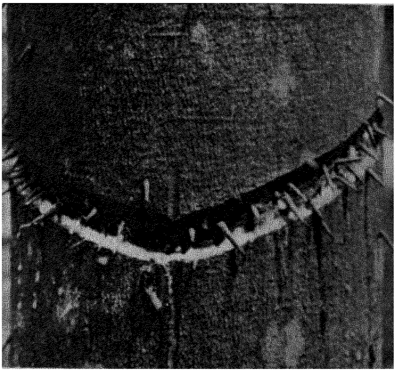


Fig. 62.—Bag Worms (*Acanthopsyche snelleni*) on tapping panel of *Hevea*. (3/16 natural size.)

lengthy larval stage that any movement of the insect occurs. The male moths are not attracted by light and the most effective method of control is to destroy the larvae. Fig. 62 will show how these larval case-moths go to work when attacking rubber trees.

Methods of Control:

(*a*) Hand collection of the bags, whereby all the stages are destroyed except the winged males.

(*b*) Painting or spraying the trunks with:

  (i) A 2 per cent Kerosene emulsion containing 0·5 per cent lead arsenate.

  (ii) A 2 per cent Izal solution.

(iii) A 5 per cent Agrisol solution.

(iv) A 5 per cent Brunolinum solution.

If the "bag-worms" are present in small numbers only it is hardly worth while adopting any spraying methods of control as the damage done will be inappreciable.

Scale Insects

Lecanium nigrum, Nietn., *Pulvinaria* sp.

Two scale insects have been found on rubber in Malaya, viz. *Lecanium nigrum*, Nietn., and a *Pulvinaria* species. It is reported from Ceylon that *Lecanium* (*Coccus*) *viride*, Green, also causes damage to rubber.

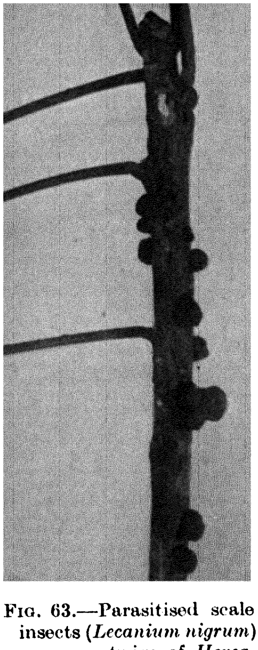


Fig. 63.—Parasitised scale insects (*Lecanium nigrum*) on green twigs of *Hevea*. (Natural size.)

In Malaya damage by scale insects is seldom met with except in neglected stands of rubber. *Lecanium nigrum* is the commonest form. When this scale is found in Malaya on young rubber, it is usually in the parasitised form, and closely resembles small, convex dark-brown to black blobs of latex about $\frac{1}{4}$–$\frac{1}{2}$ inch in length, $\frac{3}{8}$ inch in breadth and $\frac{1}{4}$ inch in height (Fig. 63). The actual scale insect is only about $\frac{1}{8}$ inch in length, and the pustular mass usually found is composed of the small dead insect enveloped in a mass of fungal filaments. The fungus which most commonly parasitises *Lecanium nigrum* in Malaya is named *Hypocrella reineckiana* and it grows over the scale in a hard cushion-like mass which is at first red-brown or yellow-brown but becomes black on ageing. These pustular masses may be found on the leaves, usually congregated about the veins and midrib, and they may also thickly encrust the terminal green stem. They are usually found on the leaves of the trees which are covered with the black "sooty moulds", i.e. *Meliola* sp.

Petch records a second fungus, *Cephalosporium lecanii*, which also attacks the commoner species of scale insects and kills them, subsequently growing out as a white fringe round each scale.

Rubber Leaf Mite

Common form = *Tarsonemus translucens*, Green

This mite is commonly known as the yellow tea mite and does a considerable amount of damage on this crop. They are very minute and scarcely visible to the naked eye; they are about 0·2 mm. long, yellow in colour, with a dark stripe down the back.

Richards reported in 1917 that small local attacks of this pest have been noted since 1914 in Malaya, mainly in nurseries.

The rubber leaf mite is a pest which under certain conditions of soil and weather is capable of doing considerable damage to young rubber fields. It punctures the epidermis of the young leaves and sucks out the fluid contents of the cells. The response made by plants affected by mites is reflected in distortion of the leaves so that they become more or less curled, causing an asymmetrical growth, or there may be complete defoliation of the young shoots (Fig. 64). Serious mite attacks are frequently accompanied by attacks of leaf fungi; the most prominent fungus over the last few years has been *Gloeosporium alborubrum*, Petch, with pinkish acervuli, but *Gloeosporium heveae*, Petch, has also been recorded.

It has been generally accepted that the serious mite attacks so far experienced in Malaya have only been found in places where soil conditions were not entirely favourable for growth. This may be accepted as a general statement, but mite attacks have been met with during the last three years where there was little wrong with soil conditions. Drainage is undoubtedly one of the important factors, and serious mite attacks are seldom found on soils which are well drained.

During 1931 and 1932 mite attacks were commonly reported, and the close association of the insect and the fungus *G. alborubrum* or *G. heveae* was very noteworthy. The combination caused a notable amount of damage in several places.

For successful control, drainage will have to be undertaken if necessary. The attacked leaves should also be dusted with powdered sulphur—four applications at five-day intervals are recommended.

From Java another but much larger mite is reported, being about 1 mm. in length. This is the so-called grey mite and the leaves react to the attacks of the insect by becoming much elongated, and the edges curling inwards.

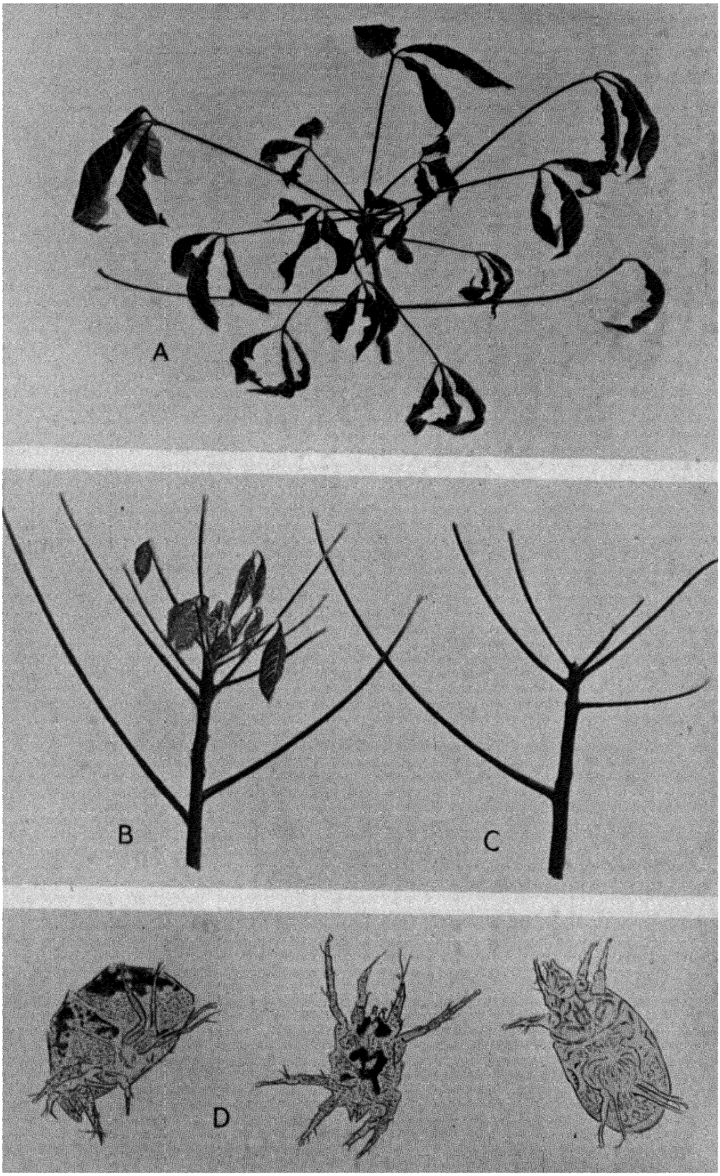


FIG. 64.—A, Young green leaves showing results of mite attack; note distorted leaves. B, C, Showing usual defoliation, B being only partially defoliated; note that when leaves have fallen the leaf stalks still remain attached. D, Illustrations of the mite insect, *Tarsonemus transluscens*. × 200.

Short-horned Grasshopper

Cyrtacanthacris (Valenga) nigricornis, Burn.

As far as the writer is aware, no special work has been done in Malaya on the life history of this large grasshopper which is distributed from South India to Java and also occurs in the Philippines. The length amounts to 60-70 mm., the colour is greenish-grey, but later the insects become yellowish (Fig. 65), the fore-wings are darker towards the base, and the hind-wings have the base tinged reddish; there is a medium yellow line and pronotum. The species is distinguished by the black antennae and the femora of the hind legs

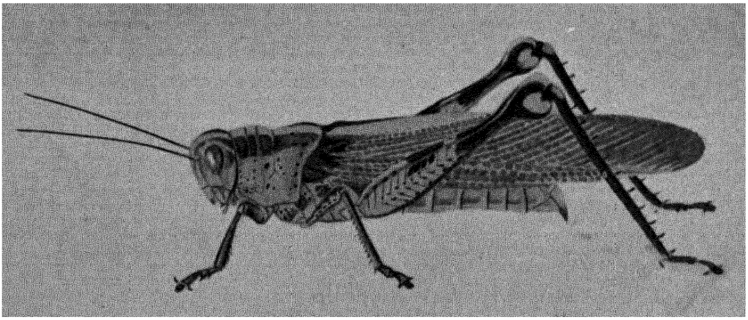


Fig. 65.—*Cyrtacanthacris nigriformis*, the short-horned grasshopper. (Natural size.)

bearing two black cross bands. The nymphs are yellow, mottled all over with black.

In Java Dammermann reports that this locust is found chiefly along the skirts of forests, especially teak forests, and in open localities within the forest. The female deposits eggs in masses of 70-100 each or more, about 5-8 cm. deep in the ground. Oviposition occurs at the end of the rainy monsoon and the eggs lie dormant during the next dry period and do not hatch before the rains set in again, in November and December and even later. The young insects become full-grown in the course of the wet season, thus completing a one-year life cycle. The hoppers, when newly hatched, live at first on the ground but soon ascend the trees to feed on the foliage. When they are full-grown, the winged adults swarm from the original breeding-grounds to cultivated areas in the vicinity, but the species does not display any social or migratory instincts, each individual travelling by itself.

It is reported from Java that usually only a small strip of land, a few kilometres wide, bordering on the forest, is attacked; further away the damage is unimportant. This is not so in Malaya, where the insect is generally distributed throughout any clearing of young rubber which possesses a dense cover crop. According to one authority teak is the most preferred food plant, the next being coco-nut and maize. The insects have been found attacking *Castilloa*, *Hevea*, *Artocarpus*, banana, coffee, dadap and many green-manure plants. Rice, as well as lallang and other grasses are free from attack. In Malaya attacks by this insect become conspicuous both on young coco-nut and rubber plantations if giant mimosa (*Mimosa invisae*) is used as a green cover crop.

The chief damage now being done in Malaya by this insect is on young budded clearings of *Hevea* where the very young leaves, often before they are out of the bud stage, are eaten. If the leaves continue to develop they finally present a very ragged appearance and are usually found attacked by a leaf fungus and death is the result. The older fully-developed leaves are not usually attacked.

An interesting case of varied susceptibility to attack was experienced in 1932, when three estates reported that on bud-grafted areas carrying a mixed planting of various clones, the clone A.V.R.O.S. 256 was completely defoliated, while other different clones surrounding the defoliated plants escaped attack entirely.

This grasshopper is not usually present in very large numbers and the usual method of control is hand-collecting by the small children of the labour force. If, however, they are very numerous and are causing material damage, the cover crops in which the insects are living should be sprayed with lead arsenate solution (2 lbs. of lead arsenate paste or 1 lb. of lead arsenate powder to 50 gallons of water).

The use of poison baits has also proved successful. For this purpose 4 ozs. of sodium arsenate is well mixed with 25 lbs. rice bran and a little water, and small balls of the mixture are prepared. In the absence of cover plants, the balls are broadcasted at the rate of 7½ lbs. per acre; where a cover is employed the poisoned balls are placed on the ground in small heaps in order to prevent any burning.

Atractomorpha psittacina is the most common grasshopper found in the green cover plants in common use to-day and for purposes of comparison a line drawing of the insect is given (Fig. 66). It is much shorter than the short-horned grasshopper, attaining a length of only 30-40 mm. as against 60-70 mm. It is characterised by a pointed conical head.

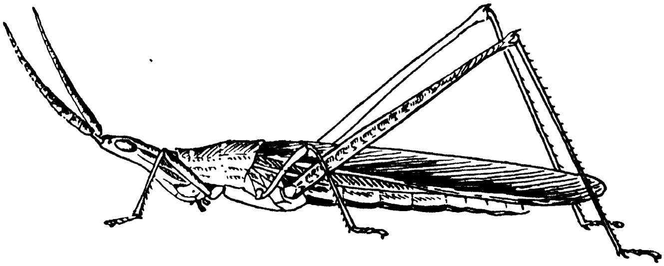


FIG. 66.—*Atractomorpha psittacina.* A small grasshopper found commonly in young rubber fields. (Natural size.)

CRICKETS

Brachytrupes portentosus, Licht.

The large cricket *B. portentosus* (*B. achatinus*, Stoll) is reported to cause damage in nurseries by biting off the young plants one or two centimetres above ground-level. The writer has no record of this, but during the last two years several reports have been received to the effect that these insects have been seen and caught eating the new bark forming on the tapping panel ½ inch above the tapping cut. There is no reason to doubt this statement, as the writer has seen the insects at work.

The insects live in holes in the ground, where they remain during the day, emerging at night. Heavy rains drive them out of their holes, and for control it has been suggested that seed beds or nursery beds should be watered thoroughly or even inundated for a short time. Petch suggests the use of poison baits, to be made by chopping up young maize plants and mixing a little treacle and 5 gms. of paris green or arsenic with each pound of the chopped plant.

Pratt stated that a cricket was reported from Sumatra in 1906 as damaging young rubber seedlings. The insects saw through young plants at the base of the stems, leaving a stump one to three inches high. The attacks were circumvented by enclosing the young plants in a paper cylinder made from ordinary newspaper. A full sheet is rolled up into a cylinder the height of the paper and about six inches in diameter, and fastened with three pins. These are placed over the stumps and fixed in position by means of three thin stakes on the inside.

RHINOSCEROS BEETLES

Xylotrupes gideon, L.

Petch reports that Pratt has seen in Malaya an area of young rubber, 300 acres in extent, entirely devoid of leaves owing to the attacks of the insect commonly known as the Fork-horned Rhinosceros beetle. The stumps are attacked soon after planting out, as soon as the shoots appear. The young shoots are bitten off and the process may be repeated as often as new shoots appear, until the plants are worthless and have to be replaced. The same method of control as that given for crickets is recommended.

The writer has not been able to verify Pratt's report, and damage by this insect has not come within his experience.

WEEVIL

Eumeces squamosus

Pratt reported about 1910 that this weevil was causing damage to young rubber trees by eating away the older leaves and young shoots. Collecting beetles by hand has proved effective in control. The beetle is practically omnivorous and, according to Pratt, is not likely to confine its attacks to rubber, but will continually appear and attack small areas of young rubber trees. A report of this insect by Wray, under the name of *Astycus lateralis*, may be found in *Perak Museum Notes*, vol. ii. pt. 1, p. 61.

The writer has never seen this insect at work and over the last few years no specimens have been sent in.

LONGIHORN BEETLE

Batocera rubra

This longicorn beetle has been recorded from Ceylon as being found boring into the tap-root or the lower parts of the stem of *Hevea* plants. Only one case has been recorded from Malaya on *Hevea*.

CHAPTER XIX

ANIMAL AND OTHER PESTS

Elephants—Wild Deer—Wild Pig—Goats—Rats—Squirrels—Spiders—Slugs.

INTRODUCTION

PETCH states that all the common herbivorous animals show a partiality for *H. brasiliensis* and that horses and cattle devour the foliage greedily. The writer has not specially noted this, though bullocks have been commonly seen grazing under rubber trees without making any attempt to eat the foliage, which was within easy reach. The list of animals causing damage to rubber trees in Malaya are listed above and fall in the orders given below:

MAMMALS	. .	Elephants
		Wild deer
		Wild pig
		Goats
RODENTS	. .	Squirrels
		Rats
ARANEAE	. .	Spiders
MOLLUSCA	. .	Slugs

ELEPHANTS

Elephants have done and still do considerable damage in rubber plantations when they are present in large numbers in the neighbouring jungle. Even recently, the district planters' association in Pahang have had the item "damage by elephants" constantly on their agenda for discussion. It is only from a few localities, where elephants are plentiful, that damage has been reported. The huge beasts break down fencing which allows ingress of wild deer and pig, and these animals can do considerable damage in a short space of time. Elephants break off or uproot small trees, and they are said to eat the roots, the tap-root being particularly favoured. There is no systematised method of elephant-catching in Malaya, so this obvious method of reducing the numbers of these marauders is not employed.

In 1914 a system of patrols was established in the Sungei Siput district in Perak. Contact was maintained with the destructive herds

and their movements carefully noted. Paths through the forest were cut so that the patrols, armed with Chinese crackers and bombs, could move about freely, and if the animals showed any tendency to move in the direction of a planted area, they were turned in a fresh direction by firing the crackers and bombs.

Another method of preventing elephant damage is to form what is called an elephant belt around the estate. The basis of the scheme is that a belt of jungle of varying width is felled and the trees are left lying all tangled up just as they fall. A passage through such a belt of felled jungle is not easily forced. In some cases the belt is made two chains wide, and is separated from the plantation by a number of strands of barbed wire. An elephant belt recently built on an estate has been made one chain wide, and through the maze of felled timber two strands of barbed wire have been run; on the wire, at about $\frac{1}{2}$-chain intervals, kerosene tins filled about three-quarters full of loose stones have been fixed. It is reported that this particular belt has proved very successful in keeping out not only elephants but other wild animals which damage rubber trees, viz. wild deer and wild pig. Costs of establishing elephant belts will differ according to the district in which the estates are situated. The cost of one, for a belt two chains wide, was 13 dollars for five chains.

Wild Deer

This animal is the one which causes most damage in rubber plantations in Malaya, more especially if the trees are young and the estate is bounded by heavy jungle. They strip the bark from the wood from ground-level up to a height of four to six feet, and complete ringing of the stem is often brought about.

Many repellent preparations have been tried but so far unsuccessfully; most of the preparations tried are themselves positively dangerous and more damage has been done by their use than would have been done by the offending animals. Constant attention to fencing or the formation of an elephant belt on the lines described above are the only sure methods of preventing damage by deer.

Wild Pig

Similar remarks apply to these animals as to wild deer, except that in addition they injure the roots of rubber trees by grubbing up the soil during the feeding. Elephant belts will prevent wild pigs from entering rubber estates.

Goats

Goats eat the leaves of young rubber plants freely and may do considerable damage in nurseries.

Rats

Certain herbivorous animals of the rodent order are classed as vermin because their activities are inimical to the growers of various crops. The rubber plantations in Malaya have not escaped entirely from damage by animals of this type. Squirrel damage has been known for many years, but damage by rats in young fields of rubber has only attracted attention since 1933.

Damage.—The enormous amount of damage done to many crops by rats is too well known to need emphasis. In Malaya padi fields, oil palm and coco-nut plantations are often severely attacked, and in any event the annual losses, on the cultivations mentioned, is considerable. In other countries sugar-cane, cocoa and coffee are attacked by this pest.

Fig. 67 depicts the typical signs of rat damage on young bud-grafted trees. In all cases examined in 1933 the opening of the runs through the cover crop have been quite conspicuous in the neighbourhood of the attacked trees, and this fact alone should enable planters to spot the cause of the damage. It might be mentioned here that the new fields of young rubber which have been and are being started at the present time for the purpose of bud-grafting, are planted up as quickly as possible with cover plants, and a thick cover crop is usually found growing over these fields.

There has been no record, in Malaya, of definite rat damage on *Hevea* plantations until 1933. In April scarring of the bark of a number of trees in certain fields of young budded rubber was first noted, and since that date up to the time treatment with poison baits was started, the number of trees attacked steadily increased. In all cases the infested areas carried a strong, thick growth of *Centrosema pubescens*, the rubber trees being ring-weeded. The runs and rat-holes were frequently found at the edges of the rings formed when the cover crop was cut back.

Two main areas were affected; the first, in a low-lying, poorly drained area, replanted in 1931 with budded trees, which were mostly stunted and of sickly appearance, averaging about five to six feet in height; the second area carried normal, well-grown budded trees, replanted in 1931, situated a few hundred yards away from the first

FIG. 67.—A, Showing scion stem of young budded rubber plant damaged by rats well above junction of stock and scion. B, Showing rat damage on scion near to junction and on stock below. C, Showing rat damage on both stock and scion of young budded plant directly about the junction.

area. On the stunted trees in the first area, the scarred places caused by the animals extended from the union upwards to the commencement of the green bark on the scion. The scars were mostly small, vertical, irregular oblongs and at the first glance one becomes suspicious of rodent damage. On many trees the scars are closely placed all round the stem and throughout the length of the harder, mature, brown bark portion, usually, though not invariably, leaving the more tender, recent growth at the top untouched. Sometimes the cambium and even a small portion of the wood beneath is removed.

Scattered affections may be seen here and there in between and around each area. In the second area, with well-grown normal-budded trees, the animals appear to have a fondness for the corky bark of the stock below the union and for that of the scion immediately above the union. In many cases holes have been scooped out around the stock, and the trees may be completely ring-barked in consequence, but none have died up to date (1933). Here and there the cambium is damaged, but as a rule the wood is untouched, and on the larger trees it is rare that scarring occurs above a few inches from the ground. The severity of the wounding renders it doubtful whether the trees will ever regain perfect bark conditions, but in the writer's opinion, if further depredations by the rodents can be avoided, they should do.

Control.—For purposes of control, the Department of Agriculture, S.S. & F.M.S., which runs special rat campaigns in the large padi-growing areas in Malaya, was consulted. The Director of Agriculture very kindly approved the suggestion that the Rat Destruction Officer, Krian (R.D.O.K.), should visit one estate and give advice, which proved very successful.

The R.D.O.K. decided to rely entirely on poison baits, for he thought Tamil coolies would not handle straight poison carefully enough or set steel traps properly without much supervision. Three small heaps of padi husk were placed at the entrance of each run in the ring-weeded spaces and, where occupied, holes were located and in the husk-pile three baits were placed. To make up the baits the articles listed below were well mixed together and the size varied from one-half to one inch in length and about one-quarter of an inch in diameter.

The padi husk is locally known as "sekam" and proves very useful in laying baits because the smell of the padi encourages the rats to forage for and eat the baits; the material also stands weather well. They are easily seen and do not easily disintegrate.

Two men are employed for bait-laying, one to lay the sekam and

the other to follow with the baits. Small scoops can be used to prevent undue handling, but if the operators rub their hands well at frequent intervals with a handful of sekam, the human element is masked to a large degree and scoops can be dispensed with.

A change bait should be used once the rats become familiar with the sodium arsenite baits. Barium carbonate or strychnine may be used as alternative poisons for sodium arsenite, but the price will govern the situation as to which shall be most commonly used. When a change from poison baits becomes desirable in the rice-fields owing to the sagacity of the Krian rat, it is usually made by running a line of steel traps for a night or two, followed by poisoned grasshoppers. A return may then be made to the poisoned baits.

The following articles are required for mixing in the baits recommended by the R.D.O.K.:

	Vols.	Ozs. (approx.)		Vols.	Ozs. (approx.)
Rice polishings	4	46	Water	1	24
Tapioca flour	2	45	Salt	1	3
Tallow	1	4	Sodium arsenite	–	18
Palm oil	$1\frac{1}{2}$	47			

The above ingredients are mixed thoroughly and then run through a mincing machine with a specially large delivery plate which turns out balls about the size of an ordinary marble, which is calculated to give approximately 0·696 grain of sodium arsenite to each ball. After being machined, the balls are dried and stored if not required for immediate use; they keep indefinitely.

The results obtained by the use of poison baits were very successful. Working with Tamil coolies, poison baits were made up and placed in position. On inspection four days later, it was found that practically every heap had been disturbed, and it was estimated that at least 8 lbs. (8000) out of the 10 lbs. (10,000 baits) set had been taken, and only ten trees in the twenty-five acres treated had been freshly attacked.

Dammermann gives two alternative formulae for making up poison baits for rat destruction, the poisonous ingredients being barium carbonate or strychnine.

Barium Carbonate.—This chemical is a most effective poison for killing rats and other rodents. It is not fatal to man, fowls or domestic animals, unless taken in fairly large quantities, about 1 gm. of pure barium carbonate being harmless to a chicken; a 4 gm. dose has proved fatal to man.

The following formula is given by Pemberton for preparing barium carbonate cakes as a poison bait for rats:

Mix together 1 part (by weight) of barium carbonate and 3 parts of flour, or preferably middlings, and add enough water to knead into a stiff dough which is rolled into sheets about ½ cm. thick and cut into small cakes about 1 to 1·5 cm. in diameter. The cakes are dried thoroughly in an oven or by the sun and are then ready for use. A small portion of one cake is usually fatal to any rat.

These cakes may be made rainproof by coating them, after they have dried and hardened, with a thin film of paraffin wax, which is best achieved by dumping them on to a tray in a pan of melted wax. The tray is then raised and the cakes are thrown through the air into a pan of water below.

Cakes of this type, kept in dry storage for two years, were found to be as effective as fresh cakes.

Strychnine.—Strychnine is a deadly poison to man and the majority of vertebrates. It is only applied as a bait for controlling rats or birds and is made as follows.

A mixture of 60 gms. each of powdered strychnine, powdered baking soda and salt, two teaspoons of saccharine and a cupful of laundry starch is placed in two litres of hot water and boiled slowly under continuous stirring until a fairly creamy paste is formed. This paste is poured over 25 kgms. of wheat maize or rice, all unhusked, in a wooden tub. The material is stirred until all the grains are covered with paste; it is then thoroughly dried and then becomes ready for use.

The control of rats in young rubber fields by poison baits has been treated at length because of the potential menace which accompanies any sign of depredations done by these animals. A recent letter may be quoted in relation to control of rat damage in Malaya:

Most of the sodium arsenite baits were taken and a decrease in the amount of new damage was observable. There still remained, however, a number of rats in the area causing fresh damage to the trees and it appeared the rats had become wise to the bait.

A suggestion was made for a change of bait, and forty pounds of barium carbonate was procured and distributed in the affected area. This bait seemed less acceptable to the rats and much of it was untouched. Subsequently, this poison was mixed up in powder form with cooked rice and distributed. Latest reports are that almost the whole of this has been taken; at the same time there is only very scattered and slight gnawing of the trees observable.

While baits are being taken it is certain that a number of rats are still left in the area, and more poison is being obtained and will be distributed

by the last method. No estimate of the number of rats destroyed is obtainable as carcases are rarely found. The extent of damage is the only guide to the efficacy of the mixture.

SQUIRRELS

The Malay squirrel, *Sciurus vittatus*, Raffl., is a very important pest in coconut plantations, but does not often cause much damage in rubber plantations. There are certain periods, however, when reports of damage by squirrels become more frequent and it is probably during the season of the year when the rich, oily seeds cannot be found in the plantations. Thus as attacks of *Oidium heveae* may wholly prevent seed production in certain years, it might be expected that more squirrel damage will be reported from rubber plantations during the years when *Oidium* attacks are severe and extensive.

The damage done is quite typical; the animals attack branches, usually about three to four inches in diameter, and eat out a narrow channel, half an inch in width, in the cortex; all the cortical tissue down to the wood is gnawed away on an ascending spiral (Fig. 68 *c*). This channel has serrated sides, for as the teeth bite into the tissue, little projections of cortical tissue remain untouched as would be expected from the action of animals with prominent incisor teeth. The ascending, spiral channels, with serrated edges, found on the branches, soon become filled up with callus tissue and a prominent, raised ridge is formed (Fig. 68 *a*). It was puzzling to account for these raised ridges at first, for they closely resembled young stems of rubber plants up which climbing plants had been growing. Ultimately, specimens were observed in the very early stages which left no doubt as to the cause. There is no necessity to treat the wounds made on the branches, as good natural recoveries are usually made.

There is a more serious type of damage done by squirrels than that described. This happens when the animals descend to the level of the tapping panel and commence to gnaw away the recently renewed bark of the tapping area. Large areas of tapping surface may thus be removed and a very ugly wound appears as a result (Fig. 68 *b*). When this type of damage is found, the open wounds should be covered in the usual manner with a dressing of asphalt or tar.

Shooting or trapping the animals is the only satisfactory method of reducing the number of squirrels. Trapping is systematically carried out on many coconut plantations.

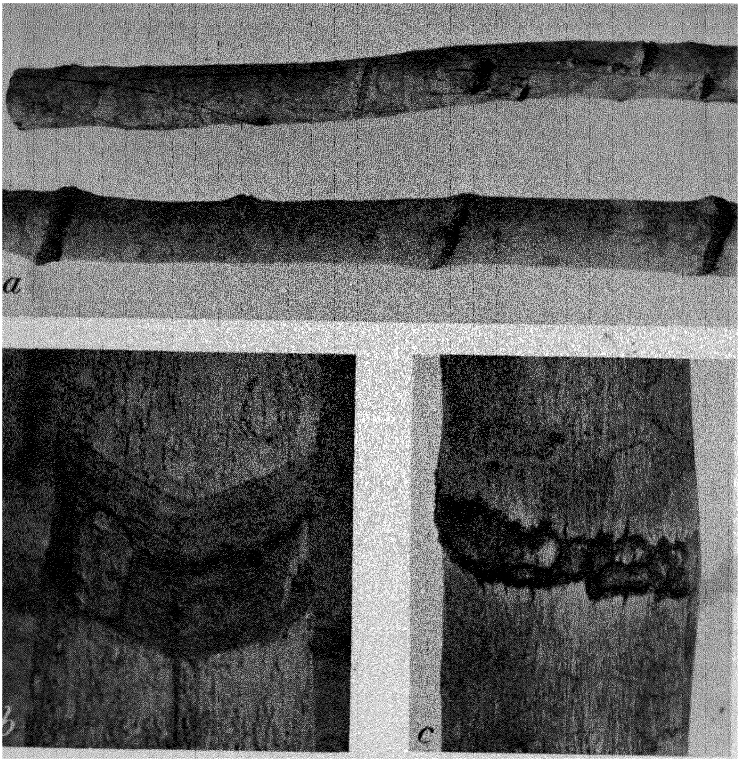


FIG. 68.—*a*, Showing repair of squirrel damage on branches; note darker, raised ridges, formed by development of callus tissue. *b*, Showing damage done on tapping panel by squirrels; note large, open wound on left. *c*, Squirrel damage on branches; note bark tissue eaten away down to the wood, forming a kind of channel, with typical serrated edges.

SPIDERS

Attention to spider damage has been directed on page 299. The following short remarks are but repetitions.

During 1933 a certain amount of leaf-fall of newly refoliating leaves developed after wintering. This was initiated by a small spider, as yet unnamed. This insect is very quick in its movements and is very difficult to capture. Up to date, the spiders seen and captured are variable in colour and there may be more than one species concerned.

This spider weaves its threads around the young pendant leaves in the very early stages of their development. In this way the leaves

are bound together in triplets and, as they grow and expand, the space between them forms an ideal damp chamber for the development of leaf-spotting fungi, viz. *Helminthosporium* and *Gloeosporium* species. Excessive accumulation of moisture within the enclosed space causes death and rotting of the leaf-tips, which later are torn apart. Finally, the leaves appear malformed, the tips are badly discoloured and torn, while healthy parts of the leaves have been severely eaten away, and the remaining leaf tissue is attacked by leaf-spotting fungi.

A leaf-eating weevil is also fond of the shelter provided by the bound leaves and is responsible for some damage. This insect has been identified as *Phytoscaphus leporinus*, Faust, fam. *Cinculionadae*, by Mr. H. M. Pendlebury, Curator, Selangor Museum. This pest has been reported from Selangor, Perak, South Kedah and South Johore, and is probably widespread in Malaya. It seems to prefer a wet wintering season.

While defoliation occurs about the same period as *Oidium* leaf fall, the symptoms are quite distinct, for leaves which have fallen owing to attacks by this fungus have not the same ragged and torn appearance, although they may be malformed.

Trees which suffer from attacks by this spider recover naturally as climatic conditions become more favourable to growth, but if treatment becomes necessary, sulphur dusting will have to be undertaken.

Slugs

Damage by slugs was recorded in Malaya in 1905 and, in Ceylon, Green published an article on the subject in 1911. Over the last decade there has been little damage done by these molluscs in Malaya. The following account is taken from Petch's book:

Early in the history of plantation rubber in the East it was found that slugs ascended the tree and drank the latex either as it ran down the tapping cut, or after it had collected in the cup. In Ceylon the species which acquired this habit is a brown slug, *Mariaella dussumieri*, Gray, while in Java, a different species, *Parmarion reticulatus*, Hass., has adopted the same practice.

As long as these slugs confined themselves to drinking the latex their presence was disregarded. The chief result in the case of the Ceylon species was said to be a loss of scrap rubber. Keuchenius, however, has shown that where these slugs are abundant the loss of rubber, owing to their consumption of latex, may be fairly large. He calculates that if each slug drinks a cubic centimetre of latex per day, then ten thousand will cause a loss of 150 pounds of dry rubber per month; and he instances one case in which over 37,000 slugs were collected in a period of three weeks.

In young rubber trees slugs have caused great damage by an entirely different method of feeding. During a spell of dry weather, caterpillars, snails and slugs commonly leave their accustomed haunts and feed upon any succulent tissue which attracts them. They climb up the stems during the night and eat off the terminal bud. New buds then develop and these in turn are bitten off. On the shoot in the centre, the apex is clubbed and consists of a number of arrested shoots, while lower down the stem the leaves have disappeared, and side-shoots, some of them similarly clubbed, have developed, though the stem was still green. The apices of other two shoots are similar, but each of the stems have developed several side-shoots; the tops of these side-shoots have been attacked and on one of them buds have appeared lower down and are giving rise to branches.

Under normal conditions each of the leaders photographed would be a straight green stem, growing only at the apex; but in each case the apex has been converted into a cluster of short shoots, most of which have not been permitted to develop further, while on those which have temporarily

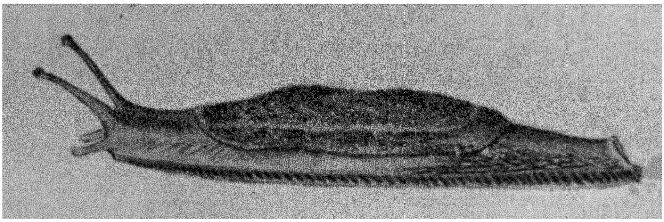


FIG. 69.—*Mariaella dussumieri*, Gray.

escaped injury and grown for a short distance the same process is being repeated. This may be continued until the plant dies. In any case the damage is serious, as the development of the plant is arrested, and they may be so distorted as to be worthless.

These slugs feed chiefly at night. Hence they are not generally observed in the act, and the injury may be attributed to insects. During the day-time they may be found under dead leaves, etc., etc., round the trees, or on the underside of living leaves on the tree itself. In Ceylon, they were found climbing the stems in the evening. Plants which had branched were not severely attacked, those which suffered most being the single-stemmed trees; the latter, after wintering, were not permitted to come into leaf again, every fresh green shoot being nibbled off and the green epidermis gnawed.

The slugs probably drink the latex because of the sugar which it contains,[1] and they appear to attack the buds in order to obtain the latex.

Mariaella dussumieri is a yellowish-brown slug, mottled with darker

[1] This sugar is Quebrachitol and its presence in latex has been reported by several observers. If further information regarding this particular sugar is required, the paper by Rhodes and Wiltshire (*Jour. Rub. Res. of Mal.*, vol. iii. p. 160) should be consulted.

dots and streaks. It is usually two to three inches long, but is said to grow to eight inches in India. The mantle, i.e. the fleshy fold which covers the middle of the body, bears two narrow ridges. Its minute shell is entirely hidden by the mantle.

Parmarion reticulatus bears a small, thin, shield-like shell on the mantle.

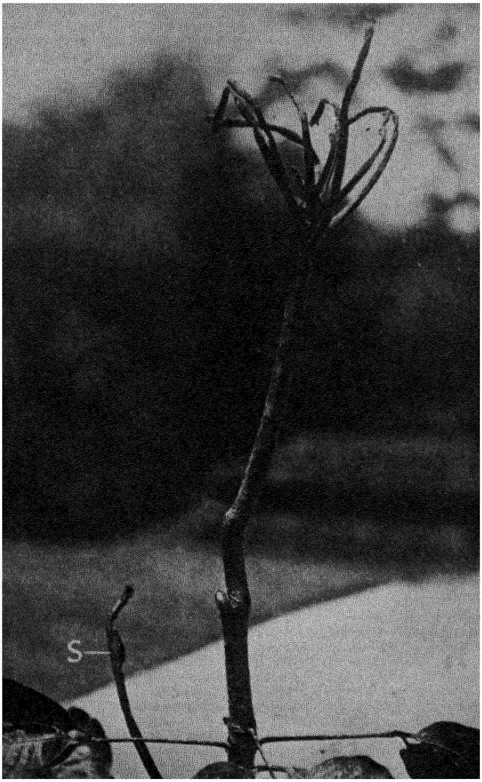


FIG. 70.—Photograph illustrating type of slug damage seen in Malaya recently. (About $\frac{1}{16}$ natural size.)

S, Slug on branch.

Collection of the slugs has proved the most practicable method of dealing with this pest. Dead leaves, etc., should be raked away from the bases of the stems, and the field clean-weeded. The heaps of dead leaves may be utilised as traps for the slugs. The latter may be killed by dropping them into a weak solution of Izal or some similar soluble disinfectant.

A report of slug damage was received in 1933. Fig. 69 shows

the natural size of this slug, and it conforms to the description given for *Mariaella dussumieri*. Fig 70 shows the type of damage done in this particular case.

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CHAPTER XX

TREATMENT OF DISEASES

Disinfectants and Fungicides—Tars and Tar Derivatives—Asphaltum and Bitumens as Wound Covers—Tests of Fungicidal Preparations, derived from Coal Tar, against Mouldy-Rot Disease.

DISINFECTANTS AND FUNGICIDES

THE general adoption of spraying methods for the control of plant diseases and insect pests in temperate climates is well understood by Europeans engaged in tropical agricultural industries. It is obvious, however, from a perusal of the recommendations made in this book for treatment of rubber-tree diseases, that spraying is seldom resorted to in Malayan rubber plantations. Nowell states in his book that "the spraying of plants, whether for insecticidal or fungicidal purposes, has come little into practice in the West Indies, and less for the latter than the former purpose"; thus the position in the western tropics is similar to that in the rubber plantations in Malaya. This author gives a list of reasons for his statement, and some of them apply equally for Malaya. The main difficulties met with, in the utilisation of modern spraying methods for control of rubber-tree diseases in Malaya, are those connected with an adequate supply of suitable water for the preparation of the solutions required, and those concerned in the efficient spraying of tall trees ranging from sixty to eighty feet in height, or even more. For these two reasons, entirely apart from question of costs, it is evident that, if satisfactory results can be obtained, dusting insecticidal or fungicidal powders with power dusting machines will prove the most practical method. Other reasons, given by Nowell for the position found in the West Indies, apply equally well for Malaya, such as "the general unsuitability for spraying operations of the type of labour employed, to the difficulties of maintaining the apparatus, especially rubber parts, in order, and not least to a reluctance to face the trouble and supervision involved". It is only fair to planters in Malaya, to remark that the last reason given by Nowell has never been much in evidence if the trouble encountered has proved to be of serious dimensions.

It will be convenient, at this point, to make a short extract from Nowell's book, on the use of fungicides:

The use of fungicides may be (1) protective against infection, as in the spraying of leaves and fruits, the dipping of sugar-cane cuttings, and the coating of exposed wood; (2) remedial, as when a fungus growing on the leaves of a plant is directly attacked; (3) disinfectant, when fungi, bacteria, or their spores existing on seeds or other planting material, on a growing plant, or in the soil are destroyed to prevent infection.

By far the most important function, in the extent of its application, is the protective one, and the most common misapprehension regarding fungicides is that spraying designed for this purpose is of value as a remedial treatment, which very frequently is not the case.

Bordeaux Mixture is the standard protective fungicide, but it has little remedial value. For the destruction of a fungus on living organisms, which naturally can as a rule only be attempted when the mycelium is superficial, the sulphur fungicides are, in general, most effective. For disinfection various poisons are available for different purposes, such as mercuric chloride, formalin and copper sulphate.

With reference to the terms used in the above extract, those in current use amongst planters in Malaya are *preventive* against infection, and *curative* instead of remedial. Thus, preventive and curative painting are commonly spoken of when making recommendations for treatment of panel diseases by means of solutions of fungicidal strength, prepared by diluting disinfectant preparations, which are derivatives of coal tar.

The last sentence brings up the question of the exact meaning attached to the terms fungicide and disinfectant. These terms are often used by the layman as interchangeable. This usage has arisen because it has been found that diluted solutions of certain well-known brands of proprietary disinfectants are quite efficient when used to control the spread of panel diseases and practically all other tree affections where fungicides are required in Malaya, with the exception of *Oidium* leaf-fall disease.

A disinfectant, in the strictest sense, is an agent utilised to purify anything from contagious matter, i.e. in the matter of a plant disease, to kill the parasite without any reference to its effects on the host plant. It is obvious that when considering a plant disease, the host plant claims as much consideration as the parasite, for it is useless to recommend for control any preparation which kills not only the parasite, but also the host plant. A fungicide is a preparation which kills the fungus but allows the greatest possible margin of safety for the host plant. There is, therefore, a wide distinction between a disinfectant and a fungicide. The point is clearly illustrated in the field tests conducted in Malaya with various disinfectants for the control of mouldy rot. Several have been tried at various dilutions and most

were quite satisfactory as regards killing out the causal fungus. But a further result of the application had occasionally to be reported. There was a definite hardening of the tappable bark areas in the vicinity of the tapping cut, and owing to this, these areas proved very difficult to tap satisfactorily and a pronounced decrease in the yield of latex took place. The tapping coolies quickly showed strong objections to the use of these preparations, and it was obvious that they could never become suitable fungicides for the purpose in view, when such after-effects were produced. As disinfectants they were, no doubt, satisfactory and probably showed satisfactory reactions to the Rideal Walker test, a subject referred to in a later paragraph.

Many well-known brands of proprietary wood preservatives, such as Solignum and Brunolinum, have been recommended for treatment of rubber-tree diseases; also disinfectants such as Izal and Jeyes' Fluid, which have been used with good effect in treatment of certain diseases. But most of these substances have certain defects. The wood preservatives require a soap solvent to effect complete solution and, under estate conditions, this does not prove too simple in practice. Strong disinfectants must be used in weak solution, but even so there is not a very wide margin of safety for the host plant. A later development by the manufacturers of wood preservatives was to produce a preparation, probably similar in composition but simpler to mix, and with true fungicidal properties, which would allow a wide margin of safety for the host plant. The simplest mixture which can be employed is one capable of complete solution with water. For this purpose, the addition of a stabiliser to maintain the preparation in a water-miscible form is required; the nature of this stabiliser is usually kept a strict secret. The water-soluble forms of brands of wood preservatives are prepared so as to allow a wide margin of safety to the host plant so that there can be little doubt of their fungicidal nature.

The preparations now in common use for the curative treatment of fungus diseases in rubber plantations in Malaya can be placed in two classes, though both have one feature in common, viz. that they are derivatives of coal tar. These classes can be distinguished as follows:

(1) Water-soluble forms of well-known wood preservatives (Agrisol is described by the manufacturers as water-soluble Solignum, and Brunolinum Plantarium as the water-soluble form of Brunolinum wood preservative), which may be said to allow a margin of safety so wide that they can be considered to possess true fungicidal properties.

(2) Disinfectants, solutions of which show effective fungicidal

properties when used in suitable strengths, usually in weak solution. Izal is the most widely used disinfectant of this type in the treatment of rubber-tree diseases in Malaya. It should not be used in a solution of greater strength than 3 per cent in the treatment of panel diseases, for there is definite evidence of bark damage if a 5 per cent solution is used.

After the explanations given above, all confusion in the minds of planters should be dissipated. One further point arises with regard to this question of disinfectants and fungicides. The strength of a disinfectant is usually given in terms of the Rideal Walker standard. This test has been in use for a long period of years for testing the strength of disinfectants, and is accepted as a perfectly satisfactory test *for disinfectants as regards bacterial strength.* In the Rideal Walker test, a pure culture of a bacterial organism is used as a standard and the death-point of the organism when placed in contact with the preparation to be tested, indicates the comparative strengths of different disinfectants.

The manufacturers of proprietary disinfectants and even of fungicides based on wood preservative solutions have apparently maintained their belief in the efficacy of the Rideal Walker reaction as a guide to the fungicidal properties of their preparations. They have received some support for their attitude by the mistaken attempt made by certain investigators in Malaya to apply a variation of the Rideal Walker technique, by substituting for the bacterial culture a pure culture of the fungus causing a panel disease; varying percentage solutions of the preparations to be tested are then made up and a certain quantity is added to the culture to ascertain the strength required to cause death. As stated above, the attributes of a disinfectant and a fungicide are widely separated and little can be gained by employing a standard useful for the former, with the expectation that it will prove equally useful for the latter.

As regards plant-disease treatment in Malaya, all laboratory tests designed to obtain information regarding the fungicidal properties of any preparation for disease treatment must be subordinate in value to tests carried out in the field. The same remark will apply in most cultivations, but laboratory tests may provide useful information when field tests prove difficult to organise. In Malaya the greatest difficulty met with was to find a suitable locality for test plots which were situated not too far distant from the laboratory, so that easy supervision, which is a *sine qua non,* was provided for. The writer has consistently maintained, since 1920, that laboratory tests on preparations derived from coal tar were of little value as a true guide

to their fungicidal activities in the field, for there is little knowledge available as to the exact composition of these preparations, and as they are composed of a heterogenous mixture of substances, there is, obviously, a chance of great variations being met with, more especially if there is no guarantee that their composition would be stabilised. That this factor is recognised as one of importance at the present day is indicated by the resolution proposed at the Imperial Mycological Conference, held in September 1934, which read as follows: "This Conference agrees in future to undertake no tests with proprietary fungicides unless the composition thereof is first communicated by the makers to the pathologist in charge of the tests."

Mouldy-rot disease of the tapping panel is the most serious of all the panel affections of rubber trees in Malaya, and required intensive investigations to define the most advantageous control measures. The writer was asked to undertake tests on many preparations but refused to issue official reports on their probable efficacy for the control of mouldy-rot disease in the absence of adequate field tests, costs for which had to be borne by the manufacturers. The last suggestion effectually prevented any tests being undertaken in the field until 1921, when the manufacturers of Agrisol undertook to carry out a comprehensive series at their expense, these to be organised and supervised by officers of the Department of Agriculture. Suitable plots could not be found nearer than Johore, some two hundred miles away, and the long distance added great difficulties. However, this experience proved to the writer that there was no insuperable difficulty to be surmounted in the way of organising comprehensive field tests to obtain direct information regarding the efficacy of any proprietary preparation in the control of mouldy rot, once suitably located testing-plots were found. The success attained by Agrisol, during the lengthy testing period this preparation underwent and the publicity arising therefrom, led to continued requests for similar tests on other preparations, but when attention was directed to the rather expensive nature of the Agrisol tests, the requests were usually quickly withdrawn.

On account of this question of expense, the position was unsatisfactory for a long period. In 1929 the Director of Agriculture, Dr. H. A. Tempany, convened a meeting, and the position was discussed by officers of the Rubber Research Institute and the writer, who, at the time, had accepted the post of Head of the Pathological Division of the Rubber Research Institute, but had not yet left the Department of Agriculture. It was left to the writer to organise field tests, if possible, on taking up duties at the Rubber Research Institute, and the suggestions were thrown out that an endeavour should be made

to establish an official "White List", and any preparation which passed the tests successfully would be gazetted by Government as suitable for use in the control of mouldy rot. Had it not been for the business acumen and foresight displayed by the manufacturers of Agrisol it is doubtful if the organised tests, now merely a routine matter, would have been successfully established. Great difficulties were encountered in the early stages, but as experience was gained, these were overcome, and no request for tests is now refused if the terms set out in the circular letter, given at the end of this chapter, are agreed to.

Malaya may happen to be fortunate, in so far as satisfactory proposals can be made to manufacturers of proprietary derivatives of coal tar, for the purpose of testing the fungicidal properties of their products, without insisting that the composition thereof should be disclosed. The conditions for testing are set out in the circular, and these will probably prove of interest to investigators in other countries. It might be mentioned here that there has been no dissent from manufacturing firms at the conditions imposed, although all costs must be borne by them apart from the travelling expenses of European officers. A point of interest is that these tests have provided much useful information which could not have been obtained elsewhere than in the field, so that the arrangements made can be said to have worked out with mutual benefit to both parties concerned.

In the extract from Nowell's book, emphasis is laid on Bordeaux Mixture as the standard protective fungicide, but that it is of little remedial value. This remark would also apply, in Malaya, to sulphur dusting for *Oidium* leaf-fall. Curative measures, i.e. application of fungicidal solutions so that disease-causing fungi are directly attacked, is the special feature of disease treatment in Malayan rubber plantations, though preventive or protective painting, with solutions weaker than those normally recommended for curative painting, is sometimes undertaken.

The universal use of certain long-established fungicidal compounds for combating fungus diseases has made the names of Bordeaux Mixture, Burgundy Mixture and Lime-Sulphur Mixture very familiar; the two former are copper compounds. The use of copper or sulphur compounds has never become an established feature in the control of rubber diseases except in recent years, when sulphur dusting for *Oidium* leaf-fall disease has become a common occurrence in Ceylon, Java and Malaya. In the period *circa* 1925, Ashplant showed conclusively, in South Indian rubber plantations, that "Bordeaux Mixture is a thoroughly efficient antidote to *P. meadii*, and that large-

scale spraying of rubber can be undertaken with every confidence in its beneficial results". This subject is remarked upon in the section on Leaf Diseases, under the heading of *Phytophthora* Leaf-fall.

Tentative spraying experiments with Bordeaux Mixture were carried out in Malaya by Bancroft in 1912, and by Brooks and the writer together, in the years 1913–14, with the object of obtaining information regarding the use of Bordeaux Mixture for combating pink disease. Beyond becoming well acquainted with the many difficulties to be surmounted when spraying tall trees with fungicides, few encouraging features were noted. It is fully realised that manufacturers have improved all spraying machinery to an enormous extent since the date of the above-mentioned work, but it has already been remarked that, in Malaya, the difficulties attached to obtaining adequate and suitable supplies of water are likely to be very great, and in any event costs would be so large that the methods would prove impracticable from this point of view. This remark is well illustrated by Ashplant's work, which resulted in the development of measures which could be considered economical in the prosperous periods around 1925. The economic position changed enormously in the years following, and during the depressed period, between 1929 and 1933, expensive control measures were ruled out entirely.

In Malaya the only branch disease of importance is pink disease, and a similar remark will apply to the leaf-fall disease caused by *Oidium heveae*. These two diseases are limited in area, and at the present date many rubber areas in Malaya remain unaffected. But most rubber estates in the country are affected by some form of tapping-panel disease, and this type of affection has claimed more attention than any other up to the last two or three years, since which *Oidium* leaf-fall has claimed all attention at the wintering period. Treatment for pink disease has been given in the appropriate section.

In connection with the treatment of panel diseases in Malaya the use of proprietary compounds derived from coal tar is practically universal. The simplest types of these substances are those which are directly miscible with water, in any proportion. Simplicity of operation is of the greatest importance, for illiterate *mandors* or headmen are placed in charge of the work involved in disease treatment, and ignorant coolies have to carry out their instructions. Therefore a simple water-miscible substance, with a fair range in toxicity, would provide the ideal curative solution. Another important fact must be kept in mind. The operation of tapping opens up new areas of tender cortical tissues, which are highly suitable for infection by the fungi causing tapping-panel diseases. This tender tissue, situated in close

proximity to the cambium, is easily injured by solutions of too great a fungicidal strength, and care must be exercised in choosing the correct strength of a solution for curative painting, so that while thorough treatment is a certainty, bark-burning and the resultant serious damage is avoided.

Tars and Tar Derivatives

The substances which have been used in treatment of rubber-tree disease can be classified as under. Class (*b*) contains those compounds in common use at the present time.

(*a*) Tars.

(*b*) Tar derivatives emulsifiable with water alone.

(*c*) Tar derivatives not emulsifiable with water alone.

(*d*) Mixtures of tars and tar derivatives with wax, oils or fats.

(*a*) *Tars.*—Tar is the liquid product which results from the dry distillation of coal and numerous organic bodies. Its nature varies according to the nature of material from which it is derived, but it is always oily, viscous and of a dark colour. It is insoluble in water.

For our purpose tars may be divided into: (1) coal tar, (2) wood tar.

(1) Coal tar is a by-product of gas manufacture. It consists of a mixture of a considerable number of organic compounds, amongst which are benzene, toluene, naphthalene and phenols.

(2) Wood tar is obtained by the dry distillation of wood. It is a by-product in the manufacture of pyroligneous acid and wood charcoal, also in the distillation of pine trees after the extraction of the turpentine. Thus two types of wood tar are recognised, the last-mentioned being known as resinous wood tar, the former being known as hard-wood tar.

Resinous wood tars are almost wholly represented by pine-wood tar, which is commonly termed "Stockholm tar"; it is made extensively in the forests of Sweden, Russia and Finland. It is an important commercial product and differs from hard-wood tar in containing the pleasant-smelling mixture of terpenes known as turpentine. Pine-wood tar is the residue left after the turpentine has been distilled.

Hard-wood tars are derived from woods such as beech and oak, but beech-wood tar is practically the only wood tar subjected to a straight distillation. Three fractions are usually collected, but only one is of importance for our purpose and that is the heavy fraction from which beech-wood cresote is obtained.

Tar is commonly recommended for many purposes in disease treat-

ment on rubber plantations, but the distinction between wood tar and coal tar is but little understood. Wood tar, usually known as "Stockholm tar" by planters, cannot be recommended for use, but good grades of coal tar give satisfactory results if used for the proper purpose. While the brands of coal tar may be less variable than brands of wood tar, they are still sufficiently variable, and inferior brands are sold which may cause severe damage by burning. For this reason, although commonly recommended and used as a wound cover, it is not considered advisable to utilise tar in treatment of panel diseases of rubber trees.

Cunningham considers coal tar the most efficient of all wood preservatives used in the orchards of New Zealand, as it functions as a disinfectant, a wood preservative and provides an efficient surface covering, as owing to its pliability it is able to expand and contract slightly with the underlying surface, and for this reason does not crack to the same extent as other wound covers frequently recommended.

(*b*) *Tar Derivatives emulsifiable with Water alone.*—The water-miscible preparations used as fungicides in Malaya are nearly all proprietary manufactures. Some of these have been derived from well-known brands of wood preservatives which have been used in the tropics for many years and which require soap solution for emulsification. The water-miscible compounds most commonly recommended and used in the past have been Agrisol, Brunolinum Plantarium and Izal. During the last two years, many other water-miscible compounds have been tested against mouldy-rot disease and a "White List" has been gazetted by Government.

In disease treatment the properties required for a suitable fungicide derived from coal tar are as follows:

(1) It should be miscible with cold water in any proportion.

(2) There should not be any residue; the emulsion should remain stable for several days, or even weeks.

(3) The emulsion should be milky-white unless coloured by the addition of dyes to aid supervision after application.

(4) There should be no, or very few, brown drops floating on the surface.

(5) The liquid must not penetrate more than about three-quarters of a millimetre into *Hevea* cortex, the cork layer of which has been removed before application.

In a preliminary distillation of coal tar the following fractions are usually collected:

I. Crude naphtha (first runnings), boiling point up to 100° C.
II. Light oils, b.p. 110° C. to 180°-200° C.
III. Crude carbolic oil or light creosote, b.p. 180°-200° C. to 240°-250° C.
IV. Heavy creosote, b.p. 240°-250° C. to 270°-280° C.
V. Anthracene oil, b.p. 270°-280° C. to 340°-350° C.
VI. Pitch.

For practical purposes fraction III is the only one of immediate interest, for it contains the compounds of phenols and cresols which form the basis of the proprietary fluids sold at the present time for use as fungicides for treatment of rubber-tree diseases. The crude phenols (carbolic acid) and cresols (cresylic acid) are seldom used as such; practically always it is the sodium derivative of these compounds which are utilised in the preparation of fluids with fungicidal and insecticidal properties.

The simple compounds of the phenols and the cresols and their sodium derivatives have not been utilised hitherto as fungicides to any great extent, probably because their composition varies greatly according to the source from which they are derived. Constancy of composition is absolutely essential in fungicidal solutions, and accordingly those proprietary fluids derived from coal tar must be mixed with some suitable form of carrier or stabiliser to ensure a constant composition. The differences in the proprietary fluids now in common use on the plantations largely depends on the different carriers or stabilisers used in the manufacture. The general form of stabiliser used for these fungicides are of the resin soap,, oil soap, sulphonated oil or the non-drying pot-still residue type (fats and greases.) Excess of stabiliser will reduce the fungicidal value of a disinfectant fluid, while too small an amount may allow too great a penetration of the tissues in the treatment of panel diseases. It has been stated previously that manufacturers of these fluids with fungicidal properties keep their stabilisers secret, but it is known that some allow for a wide margin of safety in so far as solutions of 30-40 per cent strength can be used with safety, while in others the safety limit is passed at a strength of 5 per cent. For many reasons the former are to be preferred, though more expensive in use.

The following fluids with fungicidal properties which are emulsifiable with water have been tested against mouldy-rot disease and, having passed the tests successfully, have been gazetted to the "White List"; they are placed in alphabetical order:

Agrisol	Used in 10-20 per cent solution
Brunolinum Plantarium .	,, ,, 10-20 ,, ,,
Black Cyllin . . .	,, ,, 5-10 ,, ,,
Cargilineum "B" . .	To be used neat daily
Izal	Used in 3-5 per cent solution
Killgerm . . .	,, ,, 5-10 ,, ,,
Kilsol Red . . .	,, ,, 5-10 ,, ,,

The fungicidal fluids that are emulsifiable with water are sometimes considered unsatisfactory for the reason that they are easily washed off by rain. As pointed out by Steinmann this is no real objection for only excess fluid will be washed away; the active penetrative fluid is quickly absorbed into the cortical tissues not yet protected by a bark layer, and this portion is firmly held even during heavy rain. In other places, where the tapping panel is covered by a bark layer, the fungicidal fluid will only penetrate through cracks or crevices, and it is precisely these places where spores would be likely to collect and develop. But in any case it would be sheer carelessness, in the majority of cases, if treatment was applied just before or during a heavy shower of rain. Given two to three hours before rain, treatment with water-miscible, fungicidal fluids will prove quite effective.

In Java it has been the custom for some years to add some dye or colouring material to the solutions of fungicidal fluids with a view to providing more ready supervision. Lime, in the proportion of 1 part to 1 part of Izal and 31 parts of water, has been recommended and used with satisfactory results. The manufacturers of Izal recommend the addition of 1 per cent methylene blue to the solutions used for treatment of panel diseases. Steinmann recommends the use of fuchsin of 1 per cent strength for Izal solutions and a 3 per cent solution for use with carbolineum. At the present date (1933), when every fraction of a cent must be accounted for, there is little demand for dyes which increase the cost of treatment; in fact it may be considered a fortunate occurrence if recommendations for any kind of treatment are carried out.

As stated above, the cresylic acid fraction is the basis of most of the proprietary manufactures used as fungicides which are derived from tar distillates. The market price of cresylic acid is very cheap, fifty cents per gallon as compared with three dollars per gallon for some of the proprietary fungicides now in common use. It was suggested, therefore, that an experimental attempt should be made to prepare a water-miscible fungicide, using commercial cresylic

acid as a base, in order to get a line as to the possibility of preparing a cheaper fungicide, to be manufactured locally. This work was undertaken by Mr. F. Beeley.

Two different preparations were successfully prepared after considerable trouble. For convenience, the mixtures were named: (*a*) Bencresyl, the stabiliser used being bentonite clay only; (*b*) Linsocresyl, the main stabiliser being linseed oil.

The constituents and proportions thereof are given below:

Bencresyl

Cresylic acid	700 c.c.
Resin soap (emulsifier)	25 ,,
Bentonite clay (stabiliser, 15 per cent in water).	25 ,,
Water	950 ,,

Pass through mill six times.

Linsocresyl

Cresylic acid	700 c.c.
Resin soap, strong solution (emulsifier) . .	25 ,,
Bentonite clay, 15 per cent in water (stabiliser).	25 ,,
Linseed oil (main stabiliser)	300 ,,
Water	900 ,,

Pass through mill six times.

The mill referred to is a high-speed paste mill, a proper emulsifying mill not being available. The above mixtures, when passed through the paste mill six times, gave a satisfactory stable emulsion, though no doubt a finer emulsion could be obtained with a more suitable mill. In mixing the above ingredients it is advisable to mix together half the water and all the soap and bentonite clay, otherwise there is a danger of the thick creamy clay falling straight into the cresylic acid and curdling at once.

When tested in the field against mouldy rot, these preparations proved as good as any fungicide yet tried; no damage by burning of the bark was experienced.

A second drum of cresylic acid, supplied by the same agency, was opened, but an emulsion could not be obtained with the acid from this drum, using the above formulae. It was later found that a smaller quantity of soap was required, slight excess of alkali apparently ruining the emulsion. Reducing the amount of soap solution from 15 c.c. to 10 c.c. resulted in the production of a stable

emulsion, which proved just as successful in the treatment of mouldy rot as the first batch.

In these small experiments, costs of production have been left out of account, but in the writer's opinion it is extremely doubtful if a cheaper local product, prepared on the above formulae, could be put on the market at the present time. During the last few months, a satisfactory fluid has been brought out at the price of nine dollars per five-gallon drum, and this is used at the low strength of 5-10 per cent. This is a very big reduction in price from fifteen dollars per five-gallon drum, the price of other proprietary fungicidal fluids.[1]

(c) *Tar Derivatives not emulsifiable with Water alone.*—These tar derivatives have to be emulsified by the addition of a certain amount of soft green soap to the water which is used to dilute the fungicidal fluids. A solution of about 5 per cent strength can be made up as follows:

Fungicidal fluid	2 pints
Green soft soap	4 ozs.
Water	4 gallons

The common and most popular tar derivatives in this class are the proprietary preparations which have been, and still are, more often used as wood preservatives than as fungicides. The following are the most commonly met with in Malaya: Brunolinum, Dougalite, Solignum, Silvertown.

There is more danger attached to the use of soap solutions of the substances mentioned, because it is not always easy to get a good emulsion and, in most cases, constant stirring must be employed, or the solution soon separates out into its constituents. Thus it seems a fairly even chance that, with illiterate coolie labour, some portions of the diseased area will get too heavy a dose while other diseased portions will get a dose which will prove too weak.

Steinmann gives an old formula for making up a so-called standard solution, as follows:

	Metric.	Avoirdupois.
Soft soap . .	1 kilogram	= 2 lbs. 3 ozs.
Boiling water .	6 litres	= 10 pints (approx.).
Fungicidal fluid .	1·2 litres	= 2 pints (approx.).

The soft soap is added to the six litres of boiling water with constant stirring until the soap is in complete solution. To this soapy solution

[1] Since writing this, the price of $9.00 per five-gallon drum has become general.

1·2 litres of fungicidal fluid are added. It is said that this standard solution will remain emulsified for a long time and emulsions of any required strength can be made by the proportionate addition of water. A 10 per cent solution is made by adding 110 parts of water to 20 parts of standard solution. This can be used as a basis for calculating the proportions required for weaker or stronger percentage strengths. The above is taken from an article in *De Ind. Cultuur. Almanak*, 1912, p. 233, by H. J. Quanjer.

(*d*) *Mixtures of Tars and Tar Derivatives with Wax, Oils or Fats.*—These mixtures have not been used commonly in Malaya, but have been recommended in Ceylon and Java for some years. In Ceylon, 95 parts of fat to five parts of tar have been used; sometimes 60 parts of fat to 40 parts of tar. Mixtures of resin and benzene with solignum or carbolinum are also recommended; they form a transparent varnish-like layer on the tapping surface, but these substances are said not to have been effective. Many firms at the present date appear to be adding various substances to their well-known fungicidal fluids, with a view towards producing a varnished surface after application; presumably this would be desirable because of its waterproofing effect. Up to date, such waterproofing preparations have compared unfavourably with the original fungicidal fluid from which they have been derived. In the writer's opinion, the best opportunity for carrying out effective treatment lies in the water-miscible types, and the other classes require but little attention.

Steinmann and Deuss have considered this subject in great detail and their observations are helpful. An abridged account of their work has been given in the *Review of Applied Mycology*, and a copy is appended after the section dealing with Asphalts and Bitumens, because of its utility to workers in the East. The only remark which is necessary is connected with the paragraph giving "Direction for testing these mixtures". Penetration tests give information of doubtful value for judging control; the only satisfactory method of trying out these preparations is by carrying on field tests, under natural conditions. Proprietary liquids, claimed to act as fungicides and to be useful in the control of panel diseases of the rubber tree, are often subjected to laboratory tests, with a view to ascertaining the fungicidal value of percentage strengths of solutions prepared from them. Tests, such as flash-point tests, viscosity tests, thermal death-point tests, are also often reported. Laboratory tests may all give what is considered to be satisfactory comparative information, but the most important feature, viz. the reaction of the tree to the application of a fungicidal fluid, cannot possibly be tested in the laboratory. In

the control of panel diseases of rubber trees by fungicidal fluids prepared from tar derivatives, laboratory tests are of little general utility in any sense.

Asphaltum and Bitumens as Wound Covers

Asphalt may be described in popular terms as a semi-solid sticky residue formed by the partial evaporation or distillation of certain petroleums. This is as true of native asphalts (those found in nature) as of those obtained by refining petroleum. Up till late in the nineteenth century only native asphalts were known, but then it was discovered that asphalt was a constituent of certain petroleums and could be recovered from them by distilling off the volatile oils which held it in solution. In 1928, over 80 per cent of the world's supply of asphalt was produced at petroleum refineries.

Asphalt or bitumen compounds have been used for treating wounds and for tree repair in general for some years in American forestry. But, up till 1928, asphalt or bitumen mixtures were not in common use in rubber plantations in Malaya as a wound cover. On estates in this country it was customary, after branch pruning, to paint the wounds with plain tar or a mixture of tar with one or the other of the proprietary wood preservatives mentioned in class (*c*) above. It is reported that tars and tar mixtures have the disadvantage of cracking and flaking away on drying, thus allowing the entry of water, followed by fungi and bacteria which begin to attack the wood thus exposed, and so cause decay. Asphalt or bitumen does not crack or flake off but merely stretches when applied to a growing surface, and, in addition, has the valuable property of being waterproof. It would therefore seem to be a very suitable substance for use on estates in place of tars and tar mixtures.

Semi-solid asphaltum requires to be mixed with a liquid medium in order to render it applicable without heat. It is a very inert material and, because of this property, substances like kerosene oil, very penetrative to and capable of killing plant tissues if applied alone, can be utilised with safety in plant-disease treatment, when mixed with asphaltum. The choice of a substance to mix with asphaltum must be decided by its cheapness and effectiveness, the facility with which it can be obtained, and its action on plant tissues.

In order to make asphaltum mixtures, it must first be melted by the application of gentle heat. Overheating must be avoided, as by doing so the properties of asphaltum may be considerably altered and

the efficiency of the mixture reduced. The amount of heat applied should be just sufficient to cause the asphaltum to liquefy completely, and the mixture being made up must be stirred constantly until a uniform consistency is reached. The common liquids mixed with asphaltum are kerosene oil, or the less refined and cheaper solar oil; the latter is in common use on most rubber plantations in Malaya for anti-malarial work. The proportions most commonly used are either 1 part asphaltum and 1 part kerosene or solar oil, or 1 part asphaltum and 2 parts kerosene or solar oil. When the asphaltum has been melted, the required proportion of liquid to be mixed is poured in with constant stirring. If the mixtures are stored at any time they should be kept in airtight receptacles in order to prevent evaporation of the kerosene or any volatile liquid used for the mixing, and if stored for any considerable time it may be necessary to warm and add a little more liquid, i.e. kerosene, before the mixture can be used. The evaporation of kerosene from an asphaltum-kerosene mixture is a big drawback unless proper supervision is maintained, for as the mixture becomes more viscous it is more difficult to apply. To overcome the difficulty, the disease coolies build a small fire and heat up the mixture, thus driving off more kerosene but making the mixture more liquid while hot, and finally the trees to be treated are given a dose of hot asphaltum, which may cause serious damage.

Sutcliffe gives the following mixtures for (*a*) branch pruning, (*b*) pink disease, (*c*) for treatment of budded stocks after cutting back:

(*a*) Branch Pruning

(1)	Asphalt (grade DX)	50 lbs.
	Kerosene oil	4 gallons
(2)	Asphalt (grade DX)	40 lbs.
	Kerosene oil	3 gallons
	Solignum[1]	40 ozs.

(*b*) Pink Disease

(1)	Asphalt (grade DX)	40 lbs.
	Kerosene oil	3 gallons
	Solignum[1]	40 ozs.
(2)	Asphaltum	40 lbs.
	Solar oil	4 gallons
	Solignum[1]	40 ozs.

[1] Brunolinum, Noxo, Dougalite, etc., can be used as substitutes for Solignum.

(c) TREATMENT OF BUDDED STUMPS

Asphaltum (grade DX) . .	20 lbs.
Kerosene oil[1]	1 gallon

Steinmann and Deuss's work in the Dutch East Indies is reviewed as follows in the *Review of Applied Mycology*:

The principal disinfectants used in the Dutch E. Indies on the tapped surface of rubber trees are described under three headings, namely, (*a*) tar preparations; (*b*) tar preparations not miscible with water; and (*c*) mixtures of tar with oil, resin, wax, or paraffin with benzene or spirit.

(*a*) The first category comprises the following preparations. Swedish or wood tar is stated to be unsuitable for the tapped surface on account of its lack of free carbon and excess of phenol and acetic acid. The so-called "blasentar" contains 8 per cent acetic acid and tar from resinous wood 12 per cent.

Coal tar should satisfy the following requirements: freedom from excess of ammoniacal water and acids; above 50 per cent solubility in benzol; homogenity; viscosity at 57·7 E and 120·7 E at 50° C., and of 5·0 E and 5·6 E at 100° C. This substance may be applied cold to the tapping surface provided a strip of 1 cm. be left free above the cut. It has the disadvantage, however, of concealing the surface so that wounds, and the like, are readily overlooked.

Water-gas is a thin fluid which penetrates to a great depth and may be used as a substitute for carbolineum.

Creosote must be free from naphthalene and its homologues and contain 3·20 per cent of phenols for the preservation of dead wood, while its specific gravity must be nearly equal to that of water (1·015, not above 1·07, at 38° C.). In order to produce a good emulsion the addition of resin soap is essential. A good preparation consists of 26 per cent resin soap, 61 per cent light creosote (sp. gr. 1·025), 18 per cent phenol, 3 per cent petroleum (sp. gr. 0·815), and 7·5 per cent each of caustic soda and water. According to Schmitz and Zeller (*Indus. and Engin. Chem.* xiii. p. 621, 1921), a creosote distilled at 270° to 315° C. is the most satisfactory for the destruction of fungi. Creosote varnishes with pitch or bitumen, and tars containing pitch or asphalt are stated to crack rapidly.

Cambisan is an expensive neutral tar which is difficult to apply in a cold state on account of its thickness.

Directions are given for testing these mixtures. The tree should be pared in two places: (1) down to the hard bark containing stone cells, and (2) as far as the soft latex vessels. The bark should be examined for depth of penetration and other properties of the mixture, ten days after application.

(*b*) Among the tar preparations not miscible with water which are in general use against mouldy rot (*Ceratostomella fimbriata*, see this review,

[1] The difference in price per gallon between a good brand of kerosene oil and solar oil was, in 1930, 60·2 cents per gallon as against 25·4 cents per gallon, so that from an economic point of view Solar oil has a great advantage.

v. p. 325) and stripe canker (*Phytophthora faberi*) may be mentioned carbolineum and solignum. Experiments with Dougalite, Noxonia, Jeyes' Fluid, Jodelite, Morbifugo, Diphenso and Pantox have only just been initiated and no definite statement as to the value of these preparations can yet be made. The results of tests with 2 per cent phenol soda, phenol (caustic) soda, phenol lime, phenol chalk, phenol NaOH, and phenol soda with chalk, were not very promising.

Carbolineum is derived from coal, distilled between 240° C. and 260° C., vegetable oil, or filtered anthracene oil. It has a specific gravity of 1·12, boiling-point 230°, great viscosity, flash-point above 120°, and is free from naphthalene.

Good results in the control of stripe canker have been given by a mixture of one part of solignum and three parts of melted batik wax, heated over charcoal and smeared on the tapping surface.

(*c*) A satisfactory preparation consists of 18·1 litres of spirit, 1·5 litres of creoline, and 6 kg. resin. The estimated price of this mixture is 37 cents (about eightpence) per litre (sufficient for 300 trees), the treatment of one tree, therefore, costing only $\frac{1}{8}$ cent.

Tests of Fungicidal Preparations, derived from Coal Tar, against Mouldy-Rot Disease

The subject of tests for proprietary fungicides occupied an afternoon session at the Imperial Mycological Conference held in September 1934. The writer had not realised that this subject was still so much debated, owing probably to the fact that all difficulties had been removed between the manufacturers of proprietary fungicides, and the scientific officers responsible for plant disease work in Malaya. As this subject is evidently of some interest in countries outside Malaya, copies of the official notice appearing in the *Government Gazette*, over the signature of the Director of Agriculture, S.S. & F.M.S., Dr. H. A. Tempany, and the circular letter drawn up by the writer and sent out by the Rubber Research Institute, are given below. The arrangements made are an outstanding example of the difficult work which can be accomplished by efficient co-operation between agricultural research stations, for the successful results obtained would never have materialised if the two organisations had decided to carry on individually, without reference to each other. If any credit is attached to the successful arrangements made, a full share must be placed to the account of Dr. H. A. Tempany, who took an active part in pressing forward the official side; a fact which was specially appreciated by manufacturers of the proprietary compounds.

The following notice was published in the *F.M.S. Government Gazette*, No. 71, vol. 23, 27th March 1931:

Notice

The attention of the Department of Agriculture has been directed to the necessity which exists for the standardisation of disinfectants which are approved for use in the treatment of Mouldy Rot on rubber plantations.

(2) From the date of this notice, therefore, in all notices served by the Department of Agriculture under the Plant Disease Prevention Ordinance for the treatment of Mouldy Rot only preparations will be specified which have been subjected to test by an approved authority and proved to be effective.

(3) At present the list of such preparations includes—

1. Agrisol.
2. Izal—in certain cases.

(4) The department will be prepared to extend the list to include any other preparations which have similarly been proved to be effective, by approved authorities. It should be pointed out that certain other preparations in common use on estates have also been reported to give satisfactory results, but as these have not yet been subjected to systematic tests they are not at present included in the list.

(5) The approved authority for carrying out such tests for Malaya will be the Rubber Research Institute, and the carrying out of such tests will in future be undertaken by the Rubber Research Institute; applications from proprietors of fungicides for the performance of such tests with a view to their inclusion in the list should be addressed to the Director of the Rubber Research Institute accordingly.

(6) The tests will be made strictly in accordance with priority of receipt and also in accordance with the capacity of the Institute to deal with them when received.

(7) All supplies of disinfectants required for such tests must be furnished without charge by the firms applying for such tests, while the actual expenses involved in carrying out the tests must also be borne by the said firms.

(8) For further information regarding tests, application should be made to the Rubber Research Institute.

(9) Proprietors of fungicides and their representatives in Malaya are further notified that preparations which on samples supplied have passed the tests prescribed by the Rubber Research Institute, will only be admitted to the list provided that the proprietors are willing and able to give a guarantee that the formula for the composition of their preparations will remain unchanged.

(10) Should any proprietor of an approved fungicide desire to make any change in the composition of the fungicide, he must notify the Director of Agriculture and submit samples of the preparation in its new form for further tests if required to do so. Failure to do this may entail the removal of an approved preparation from the list.

H. A. Tempany,
Director of Agriculture,
S.S. & F.M.S.

KUALA LUMPUR
2nd March 1931

DEAR SIR,

I beg to acknowledge receipt of your letter requesting that....... .....disinfectant should be tested in accordance with the circular notice issued under the authority of the Director of Agriculture, S.S. & F.M.S. This circular states *inter alia* that the approved authority for carrying out the tests will be the Rubber Research Institute.

(2) To prevent misunderstanding the following points should be noted:

(*a*) The tests are being undertaken to provide an approved list of standard disinfectants for use in the treatment of the Mouldy-Rot disease of Rubber Trees.

(*b*) The tests will be made strictly in accordance with priority of receipt and also in accordance with the capacity of the Institute to deal with them when received.

(*c*) All supplies of disinfectants required for such tests must be furnished without charge by the firms applying for such tests, while the actual expenses involved in carrying out the tests must also be borne by the said firms.

(*d*) The right to publish the results will be retained, whether the results are good, bad or indifferent; normally, however, the procedure will be merely to enter the name of the product, if satisfactory, on the list of approved disinfectants.

(*e*) It should be clearly understood that the responsibility for the maintenance of effectiveness of any preparation admitted to the White List rests with the firms supplying the disinfectant. Any complaints received by the Institute or the Department of Agriculture respecting the effectiveness of any disinfectant admitted to the White List will be referred to the agents, and the receipt of more than three such complaints may, in the absence of any satisfactory explanation from the Agents, entail the removal of the disinfectant from the list.

(3) With reference to para. 2 (*a*) above: It should be noted that the disinfectants are being tested for use in the treatment of *Mouldy Rot only*, not for treatment of other rubber-tree diseases.

(4) With reference to para. 2 (*b*) above: The suggested tests can be undertaken only when suitable diseased areas can be found. The fungus causing *Mouldy Rot* disease is very little in evidence during dry weather, therefore the tests can only be carried out at certain seasons of the year, i.e. during rainy periods. As a result, no guarantee can be given as to when results may be expected. Firms asking for tests will be informed of the date of starting tests, etc., and, given fair conditions, a report should be available six weeks after the commencement of the test.

(5) With reference to para. 2 (*c*) above: The estimated costs will depend largely on location of test blocks. The transport and travelling charges will depend entirely on the distance from Kuala Lumpur, there-

fore Agency firms will be informed of the location of suitable test blocks and asked to agree beforehand to the estimated costs. In addition to transport and travelling, costs of supervision will have to be charged for. An outside estimate for carrying out a suitable test would be 250-300 dollars.

Yours faithfully,

B. J. EATON,

Director, Rubber Research Institute of Malaya.

Experience has shown that a field test over a period of one month is quite sufficient to give reliable information as to whether a fungicidal solution derived from coal tar is suitable for use in the control of mouldy rot. The first test slightly exceeded the estimated cost, but later, new arrangements were made so that the expenses of supervision were considerably reduced, and although costs varied slightly, the sum incurred seldom exceeded 120 dollars. Once the routine was established, it was found that manufacturers did not object to paying for tests; the main objection appearing to be that attached to disclosure of composition. This objection was overcome by the routine adopted, and since the middle of 1931 the pathological division of the Rubber Research Institute has been engaged practically continuously in testing different proprietary compounds.

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CHAPTER XXI

FORESTRY METHODS OF CULTIVATION

SINCE about the year 1930, forestry methods of cultivation have attained considerable prominence. Very wide claims were made for the improvements likely to be effected by the adoption of these methods, and therefore it seems advisable to consider the general question of cultivation methods in rubber plantations.

The recent publication of Planting Manual No. 6, by the Rubber Research Institute of Malaya, brings to a focus the primary problem in connection with the utilisation of forestry methods in rubber cultivation. The title of the publication, viz. *The Uses and Control of Natural Undergrowths on Rubber Estates*, written by Dr. W. B. Haines, is a sufficient indication of the scope of the work and immediately leads to the thought that no serious objections could be raised to the proposals likely to emanate therefrom. From the pathological point of view, it may be said at once that if natural covers are utilised with a proper regard to their control, there can be no objection to their use, any more than there can be against the use of leguminous cover crops in the early years of the plantations. As everyone is aware, this has become the common, established practice. But will the text supplied by the words "The Uses and Control of Natural Undergrowths" prove a satisfying one to advocates of forestry methods? If it proves to be so, the position cannot be misunderstood, for nothing more is claimed than that the methods will lead to soil improvements in particular areas and, as a result, there will be a direct response in increased latex yield, and no serious drawbacks need be feared. The only important problem which needs study in the uses and control of natural covers is their habit and whether they possess any undesirable characteristics, such as the formation of a matted mass owing to the type of growth of the roots; whether they are climbers; their rate of decay when cut back. In addition, thorny plants are undesirable because when cut back they interfere with the work of the labour force. If these features and conclusions could have been clearly stated at an earlier date, much confusion and misunderstanding would have been avoided.

The claims for forestry methods have been ably stated by H. N. Whitford, Ph.D., whose enthusiasm for them the writer can testify to

as a result of more than one prolonged friendly discussion. He writes as follows:

> Carried to full measure, the claims of the advocates of the forestry methods are as follows:
> (1) The capital cost per acre will be greatly lowered.
> (2) Upkeep costs will be greatly cheapened.
> (3) Supervisory costs of tapping may be lowered.
> (4) Some classes of soils of old areas can be rejuvenated at low cost.
> (5) By natural regeneration old plantations may be replaced by new ones without new capital costs.
> (6) Danger from root diseases may be lessened.
> (7) The resultant plantations may give per acre yields higher than those planted in the past.

The above is a truly formidable list, and if the future proves these claims to be well founded it would seem necessary for some person to appear as public apologist for the scientific officers most closely concerned with cultivation operations in rubber plantations and for any scientist who may have appeared sceptical as to the likelihood of the claims being fulfilled, apart from those dealing with soil improvements. The writer must admit making a serious endeavour to show the extreme improbability of many of the claims ever reaching full fruition; in fact it has never been deemed necessary to proceed beyond a discussion of the advantages to be gained by soil improvements and the probable disease reactions. Outside these particular claims, there was, and still is, a great measure of qualification to be attached. Whatever may be the final outcome, the claims made have been negatived on the estate which was considered the classical example and where forestry methods were first inaugurated. The undergrowth on this estate was allowed unrestricted growth under the forestry régime. A serious outbreak of mouldy rot occurred later and extensive damage was done. But more serious than the outbreak itself was the fact that, under the conditions existing, it was exceedingly difficult to control the disease. It was not until orders were given to cut back the undergrowth that the disease was brought under control. This outbreak of mouldy rot was unfortunate but not unexpected.

At this point it may prove of some interest to look back to the early days which saw the inception of the rubber plantation industry in Malaya, and to consider how the cultivation methods which have been in vogue for so many years arose. The basic principle of cultivation in rubber plantations up till very recent years was clean weeding, and as long as the industry remained prosperous it appeared that

little could be gained by breaking away from that policy. Advice was often given regarding the adverse consequences which would probably result from sticking to a hide-bound policy, but little attention was paid, or at least no changes were instituted. On large numbers of hilly estates it is now realised that much damage has been done by severe soil erosion.

Experience has shown that full attention should have been given to soil conservation methods, but even so, it should be recognised that, as regards cultivation in old rubber areas, the present position is but a logical outcome of the rapid development and expansion of a newly established industry. The first rubber estates in Malaya were planted on areas which had been utilised previously for growing coffee and sugar before the advent of rubber; coffee and sugar estates were planted upon coastal areas because water provided the only means of transport.

Later, as rubber-planting gained in favour, estates were opened up further inland, usually near rivers and as close to the sea as possible, for few or no roads were available at the time. Thus the earliest estates usually required extensive draining, and the clearing of all surface growths helped towards putting down an efficient drainage system and, in addition, considerably aided supervision. After several years of prosperity road communications were extended, and inland territories could be explored, the final result being the opening-up of the so-called "inland", typically undulating, rubber land, with good top-soil. At this period, as times still continued prosperous, the methods of planting and cultivation had become well established and clean-weeding methods were the order of the day even for hilly inland estates. Clean weeding was established and continued for the following reasons:

(*a*) A very important factor in the economic management of the earliest Malayan rubber estates was transport, and as no road communications were available estates were opened up either on coastal areas or near rivers.

(*b*) Soil conditions on such sites demanded, primarily, an extensive drainage system which could be controlled most efficiently by adopting clean weeding.

(*c*) On these sites soil movement, apart from shrinkage in peat areas, was of minor importance. Thus the main requirements of estates on coastal and riverine areas may be considered as diametrically opposed to those on undulating land. On the latter type drainage is seldom a very pressing problem but prevention of soil movement is of the first importance.

Under normal conditions, during the period when clean-weeding principles have been followed, fungus diseases or insect pests have never acted as limiting factors. Large losses have had to be met and more may be incurred in the future but, up to date, some form of economic control has been found applicable to all the major pests and diseases. This is a matter for considerable congratulation and should be duly stressed as an important point for the retention of clean-weeding methods in areas where they are specially applicable. It is obvious that there are large numbers of first-class estates which still adhere, more or less, to a policy of clean weeding. But the days when absolute clean weeding was pursued with fanatical zeal have passed for ever. Still, a myopic view of the present-day situation should be avoided and the good points of clean weeding should not be overlooked.

As long as substantial profits were being made in the rubber plantation industry there was little chance of any considerable modification of methods. During the last few years profits have been negligible on most rubber properties, and the search for economies has been so intensively carried out that all items of expenditure have come under strict scrutiny with a view to possible reductions. It may be said that during the long period of depression before restriction all possible economies were ruthlessly enforced. European supervision was cut down to the lowest possible level, and as regards pests and diseases, even if preventive methods were undertaken, lack of reliable supervision often nullified the work. Expense on pest and disease work was usually cut down to a minimum or even totally left out of account, and any system of cultivation which showed promises of economies was doubly welcomed. Thus, the long period of financial depression in the rubber industry provided a very favourable opportunity for the introduction of a system of cultivation which promised reductions in expenditure. When the so-called forestry methods began to be hailed as the panacea for all the ills to which rubber plantations were subject, attention had to be paid to the claims set forth, for no objections could be raised to the view that soil improvements would result from the adoption of the methods advocated.

In order to show that the last paragraph is not exaggerated, the following is cited to indicate the type of statement commonly made in the past. This statement appeared as recently as January 17th, 1935, in a weekly edition of a local daily newspaper:

He rightly points out that the whole face of the rubber-growing industry has been transformed in the space of three years or so by the discoveries in this field of two Danish planters with a flair for the practical application

of plant ecology whose methods had a special appeal for the industry in slump time, owing to the element in them of *laissez faire*, and have lately received the rather tardy blessing of scientific authority.

Because of such statements and numerous other claims which were made, it is easily forgotten perhaps that the genesis of forestry methods occurred when an attempt was made to regenerate a small area of mature rubber trees, some eight acres in extent, growing in a very hilly situation where the land had been denuded of all serviceable soil by severe erosion. The trees showed all the usual symptoms found on denuded soil. Die-back of branches had brought about a large reduction in size of the leaf canopy, which allowed for easy access of the sun's rays to the soil, which thus became overheated for the greater part of the time. In addition, the yield of latex was reduced to such an extent that it was considered waste of money to collect it. After a period of years the trees, previously poor-yielding, were again tapped and satisfactory yields were obtained; they had, moreover, recovered their normal appearance more or less and had undoubtedly improved to such an extent that the area could be entered in the lists again as an economic unit. In this case soil conditions were greatly improved by establishing a dense cover of mixed growths, and this was reflected in the appearance of the trees. There is no doubt that this effort was a notable one and deserved high commendation, but, in addition, it certainly emphasises the opinion held by most scientific officers. This has recently been stated by Eaton as follows: "The definition 'forestry method of cultivation' has been given to an aspect of the cultivation of the rubber tree which is essentially a soil problem".

Already it has been stated that the fundamental principles which form the basis of the so-called forestry methods are sound. They are as follows:

(*a*) Shading of the soil, resulting in cooler and more open top-soil.
(*b*) Prevention of soil erosion.
(*c*) Supply of a suitable type of humus.

No scientific worker could possibly deny that the factors mentioned are of considerable importance. But it is obvious from preceding pages that the claims of the supporters of forestry methods go far beyond the requirements of soil shade, soil erosion and supply of a suitable type of humus. If these factors were the only ones in question the natural outcome of the present-day practice of establishing a light-loving leguminous cover plant in the early years of the plantations would be to attempt to establish a low-growing shade-loving cover plant, and to maintain the same for as long as possible.

Shade, i.e. a constantly decreasing amount of light, is the limiting factor in the development of the cover plants which are established in young rubber plantations for shading the soil, preventing soil erosion and supplying humus. Shading of the soil is of great importance in flat land areas where soil erosion is not an outstanding feature; the latter factor is probably of greater importance than any other on undulating or hilly lands. Leguminous cover plants can be most easily established in the early stages of a rubber plantation and are the most easily controlled, and therefore will almost certainly be preferred to a mixed natural cover. As the branches of the rubber trees grow in length, casting more and more shade as the length increases with age, any light-loving cover plant gets thin, patchy and finally dies away, to be replaced in course of time, if allowed, by a mixed natural cover.

From the pest and disease point of view, the position in the rubber plantations of Malaya at the present date is not unsatisfactory. Therefore any fundamental change in cultivation policy has to be considered carefully, more especially if the suggested changes will, according to phytopathological knowledge, encourage the incidence and spread of various diseases. From this point of view, any ground cover chosen must be capable of easy control and cultivation methods must never be allowed to interfere with supervision of and control measures against pests and diseases. There can be no doubt that in young plantations the usual leguminous green covers are most quickly established and most easily controlled. But they cannot be utilised in more mature rubber areas because of excessive shade. The writer is of the opinion that a low-growing leguminous green cover, capable of normal development under shade, would be preferable to a natural cover formed from the mixture of plants developed under forestry conditions. Some success has occasionally attended the use of *Vigna oligosperma* under mature rubber trees, but there is yet to be found a shade-loving leguminous creeping cover plant which will develop under normal plantation conditions in Malaya.

As stated in a previous chapter, systematic inspection and treatment of root diseases in the first four to six years of the plantation will result in the practical elimination of root disease in after years, and if this desirable end is attained one of the great objections to forestry methods, as applied to mature rubber, will be removed. It would seem logical, therefore, to propose that good use could be made of creeping light-loving leguminous cover plants in the early years of a rubber plantation, and, at a later period, of shade-loving low-growing cover plants which should be allowed to become established

under mature rubber; but a *sine qua non* to this proposal is that complete control must be established and maintained before such a scheme could be considered satisfactory. In view of the preceding remarks, it is obvious that provision of cover plants, in the early and later years of a rubber plantation, should be but complementary phases of a complete scheme. This position has always been quite clear to the writer and he fails to understand how it can be considered that "the whole face of the rubber-growing industry has been transformed in the space of three years or so". Such a statement might lead a person unacquainted with the correct position to conclude that the majority of rubber plantations in Malaya had suffered in the past by the non-adoption of forestry methods, and therefore could not be considered first-class properties, which would be a gross misconception. The yields of rubber estates in Malaya which have been planted on suitable types of soil and have received the requisite attention will still compare favourably with those which have been obliged to adopt forestry methods for the purpose of bringing about soil improvement and, incidentally, restoring the yields.

The question of soil improvements by forestry methods has been dealt with at considerable length because it is high time that a clearer understanding should be reached. The suggestion that forestry methods "have lately received the rather tardy blessing of scientific authority" is entirely uncalled for since it implies that scientific workers in Malaya have been inclined to depreciate all the claims put forward. The foregoing explanation makes it clear that there has never been any reason for withholding support for the views advanced with respect to soil improvements. The writer has objected to forestry methods chiefly on account of the attitude adopted by its supporters towards the disease situation. The statement was made in 1931 that "the success of the forestry method seems very problematical unless there is sufficient room left in the fabric of the scheme for the insertion of a systematic treatment of root diseases", but since that date significant facts have been obtained about mouldy-rot disease. These facts allow pathological workers to broaden the basis of the statement and this should now be read "the insertion of a systematic treatment of diseases caused by fungi". The reason for the change will become obvious later.

The writer's conception of a shade-loving low-lying undergrowth following on a light-loving leguminous cover, between the fifth to seventh year after planting, in order to maintain the best conditions for soil shade and prevention of soil erosion, is one which can be definitely supported by any scientific investigator. But the forestry

claims are much wider, and once outside the orbit indicated they can be considered haphazard, difficult of control and unscientific.

The forestry, or Birkemose,[1] system of rubber cultivation is based upon treating a stand of *Hevea* as a natural balanced forest. The basic ideas underlying forestry methods are summarised as follows:

(1) The principles of forestry are to control and regulate the amount of heat, light and wind and (to some extent) the rain reaching the ground. These factors determine the success or failure of forestry.

(2) Regulation is achieved primarily through the natural ground covers, of which *Hevea* seedlings form the natural predominant features in mature areas. In new clearings considerations of shade lead to closer planting than the conventional systems.

(3) Careful attention is applied to the natural covers within the bounds set by the requirements of shade. The system is therefore much more than a mere cessation of weeding; lallang control of course being taken for granted. Some plants are condemned on the type of root systems, a close mat or tuft being considered harmful. Others are considered to maintain acid soil conditions by their root action, e.g. stag-moss. Plants with broad leaves and soft stems are encouraged. The formation of woody growth is not permitted except in the seedling rubber, which has a definite future as the dominant species and crop producer. The plants which appear are taken as an index of the stage of regeneration reached, the final improvement being indicated when the "nitrate feeders" appear—which are recognised by the greater softness and delicacy of tissue and the fresh green colour of the foliage.

(4) The selective weeding is carried out by hand, no tools being applied to the soil, for fear of root injury and soil erosion. Plants are either pulled out or cut off near the ground. All material is left to rot naturally, this being accelerated by breaking up and pressing close to the soil surface, so helping to keep both moist. The use of lime (say 6 lbs. per tree) is considered to give valuable assistance in hastening such decay and improving the seed-bed conditions for the new cover plants.

(5) No pitting or bunding is considered necessary, complete reliance being placed upon the protection from erosion afforded by the plant cover. Contour paths or narrow terraces are made for accessibility.

(6) In the main, root disease is viewed as an inevitable part of the forest complex, which will not get out of hand if natural stabilised conditions are maintained. Soil sanitation work is therefore omitted, except perhaps in preliminary stages, in mature rubber. Reliance is placed upon a sufficient number of seedlings surviving owing to natural resistance even in old disease patches. Trees for removal are either ringed and left to decay or cut off close to the ground.

(7) The maintenance of the stand indefinitely depends upon replacement of successive generations of trees growing together. Constant selec-

[1] BIRKEMOSE SYSTEM.—This refers to the name of the plantation manager who first introduced forestry methods on the estate of which he was in charge.

tion goes on, guided by appearance and test tapping, the best trees being brought on by judicious thinning in their neighbourhood. The gradual replacement of an old stand with buddings by these means is considered feasible.

The statements made under paragraphs (1), (2), (3), (4) and (5) leave little which calls for adverse comment. Paragraphs (6) and (7), however, cannot be allowed to pass without criticism. It is difficult to understand statements such as "root disease is viewed as an inevitable part of the forest complex" and "will not get out of hand if natural stablised conditions are maintained". They convey little precise meaning and it is difficult to guess the writer's general conception of the problems involved. Natural stabilised conditions disappear with the felling of the jungle, and a substitution of a jumble of shade-loving plants, of which *Hevea* seedlings are to form the natural predominant feature in mature areas, does not restore natural stable conditions. It is true that the origin and development of root diseases in rubber plantations presupposes the existence of the fungi *Fomes lignosus* and *Ganoderna pseudoferreum* in a more or less quiescent state in the jungle, because the requisite conditions for rapid spread are not normally provided in jungle areas. But if a supply of a susceptible type of permanent tree, of whatever species, is planted in the manner of rubber trees similar phenomena in respect to disease caused by *F. lignosus* and *G. pseudoferreum* will eventuate. All the evidence collected up to date strongly supports the view that it is extremely unlikely that there will ever be any development of natural resistance to this type of fungi, especially when the system of cultivation recommended would strongly encourage the vigorous development of root-disease fungi. In addition, the fungus causing the dangerous disease of mouldy rot on rubber trees is likely to be encouraged to an almost illimitable degree.

The practice of ringing trees and leaving them to decay, or cutting them off close to the ground, as suggested in paragraph (6), has been commented upon previously and was considered to be one which could not be sufficiently severely condemned from a pathological standpoint. The writer views with considerable perplexity the statement that "soil sanitation is therefore omitted, except perhaps in preliminary stages", because the reasons given are entirely inadequate and cannot be supported.

The most recent observations on mouldy rot strongly support the statement that the forestry system of cultivation will encourage the vigorous development of the fungus responsible. Only comparatively recently it has been determined that *Ceratostomella*

fimbriata is very sensitive in its water relationships, and that if abundance of moisture is provided it is practically impossible by the usual methods successfully to control the disease. The extremely large amount of water vapour given off by plants during transpiration is not generally realised by the layman, but anyone undertaking transpiration experiments for the first time is more surprised at the copious quantities of water which are transpired than at the process itself. The amount of water transpired can be expressed in standard units, but it is hardly necessary to detail them as they are of a highly technical character and must be given in terms not readily understood by the non-technical reader. It is sufficient to state that the amount of water vapour transpired is infinitely higher than is commonly thought, and if a heavy, thick undergrowth is allowed free development, large amounts of water vapour must be in evidence, even during periods of dry weather, when the fungus would otherwise receive a severe check. Water vapour transpired by plants growing under shade has little chance of free movement because of insufficient ventilation, and forestry conditions in rubber plantations will certainly bring about the undesirable hot, moist, steamy atmosphere approximating to that of the jungle in Malaya. Under these conditions it is almost hopeless to expect successful control of the mouldy-rot fungus.

With reference to paragraph (7) little need be said beyond the prediction that the claims made are exceedingly unlikely to be fulfilled. The remarks following are largely culled from a lecture given by the visiting agent on the merits and demerits of the forestry methods as first applied, i.e. unrestricted development of undergrowth combined with selective weeding. The writer hopes that the position he takes up is not misunderstood. The good ideas in the forestry methods have never been overlooked, as will be obvious to all planters who read the extracts below. But all the speculative claims, or qualified expectations, which were many, and which were aggressively thrust forward as established facts or new discoveries, etc., must be commented upon if the correct position is to emerge.

Many subjects are dealt with in the forthcoming extracts and they appear in the following order:

(*a*) Root diseases and forestry conditions.

(*b*) Mouldy rot and difficulties of securing sufficiently large crops at a reasonably low cost of production.

(*c*) Repopulation of fields of rubber with self-sown seedlings.

(*d*) Costs of production and difficulties of supervision under forestry conditions.

These items have considerable bearing on those listed by Whitford, given at the commencement of the chapter, and planters should be quite capable of appreciating the actual position after studying the details as given by an authoritative person.

The following remarks refer to the question of root diseases and forestry conditions:

Root disease certainly has occurred and does occur amongst the old trees on this estate under forestry methods though possibly the extent of its present ravages is rendered less obvious by the non-existence of the vacant spaces so commonly found on estates of similar age. The "would-have-been" vacant spaces are now filled with seedlings of varying ages and it was hoped, under forestry methods, to keep such old areas fully populated by means of these seedlings. The protagonist of forestry methods considered for some unaccountable reason that these seedlings were immune from root disease. His claim was based on the fact that as no changkol or any other cultivation instrument had been used in the vicinity of these plants they had not been exposed to any risk from mechanical damage.

The last point has been discussed in full in previous pages and the conclusion has been stressed that wounds caused on roots of healthy, vigorous plants, by whatever cause, need not be considered as dangerous factors in the question of root diseases of rubber trees.

The most important feature met with on this estate was the outbreak of a virulent attack of mouldy rot which upset most of the expectations of the optimists who supported forestry methods to the full:

Attention must be now given to those destructive agencies which damage and reduce the trees' latex-yielding powers. Special attention must be directed to mouldy rot of the tapped surface, for the increased humidity of the surrounding trees induced by forestry methods does favour, unfortunately to a most marked degree, the incidence and spread of this disease, and from the experience gained up to date it is not over-estimating the situation to state that this increased humidity of the atmosphere due to the presence of various growths between the trees, renders it a practical impossibility to keep the disease in check, at least by the ordinary recognised methods.

Prior to the end of 1931 mouldy rot had not caused much trouble on the estate under consideration. Certain slight outbreaks had to be dealt with, but by closing down the occasionally heavily infected tasks, usually made possible without loss of crop with the alternate daily tapping, by tapping daily the unaffected alternate daily task, and by carrying out periodical disinfection of the trees in the affected fields, it has always been possible to keep the disease in check. In the latter half of 1931, however, the general climatic conditions of the Malaya Peninsula favoured the

spread of mouldy rot, and heavy infections were experienced in many parts. This was particularly the case on this estate under forestry methods, and hard but ineffective struggles were made to keep the disease in check. In January 1932, however, the weather became dryer and the disease more or less ceased for the time being. The methods adopted to combat the disease, the application of tar or tarry mixtures, of whitewash or whitewash-disinfectant mixtures, helped to mask the extent of the damage caused by the disease (or by the substance applied), and it is only later that one has had a better opportunity of assessing the amount of damage done. With this uncontrollable outbreak of the disease not only were the bark reserves of the trees seriously injured—and the tappable bark reserves are regarded by many as the capital of an estate—but the crops were reduced, tapping difficulties arose, the Chinese contract tappers were unsettled, since with the badly infected tasks one could not permit uninterrupted tapping, and the whole situation caused and is still causing extremely great worry. With the later return of wet weather the disease has reappeared though not quite to the same extent as at the end of last year. The dread of the occurrence of mouldy rot has become a nightmare to both the manager and visiting agent of the estate, for both appreciate their inability to keep the disease in check during spells of wet weather and also to turn out the crops which are so needed at the present time in in order to *secure a reasonably low cost of production.* It will be readily appreciated that it is very little use growing rubber trees if our methods of maintaining our estate precludes us from tapping those trees.

In view of the continued trouble with mouldy rot, particularly in one field, the present manager has more recently slashed down the rough growths, leaving an unslashed control patch in the middle of the slashed area. Later, the manager reported that the slashed area had been so far free from fresh attacks but in the unslashed control plot the disease was occurring still with its previous virulence.

While admitting the forestry method of maintenance will secure a definite soil improvement on eroded areas or will prevent any loss of natural soil fertility, yet, on estates similar to the one under consideration for climatic conditions, with that method one jeopardises the lives and the health of the trees by being unable to control the spread of root diseases, one runs the risks of crops being interfered with by outbreaks of mouldy rot to an uncontrollable degree and of permanent and irretrievable damage being done to the tappable reserves of the estate.

With reference to repopulation of fields of old rubber with self-sown seedlings, the following remarks are to the point:

But it will be gathered from what has been written above that under the forestry method of conducting an estate, losses of trees by disease, of bark reserves through mouldy rot are matters of not really great importance. The interference with tapping by mouldy rot is certainly a nuisance but as a continual repopulation of the fields is to go on, the young seedlings will eventually take the place of those older trees which succumb to root disease, or which have been depleted of tappable bark by disease

and become thus valueless as latex yielders. This sounds well in theory, and the possibility of not only maintaining the "trees per acre" stand in this manner but also of increasing it, cannot be denied. The question then arises, are these repopulation trees of a desirable type? The young self-sown seedlings make but very slow growth. During the first year their growth is generally fairly good, but with each succeeding year the rate of development gets slower and they do not attain a tappable girth until they are nearly ten years old. Even then attention has been given to afford them the maximum space possible for their development under the scheme. The tall neighbouring trees which overtower the younger ones must hinder their development, and it is only natural that the younger trees become attenuated and lanky. They cannot attain a reasonable girth until they have grown so high as successfully to break down the competition from neighbouring trees for light and air. It is perhaps too early to judge the ultimate possibilities of these repopulated trees but it cannot be denied that their early development is much slower than that of trees grown under ordinary estate conditions, and hence their time of reaching a tappable maturity is considerably delayed.

It will be appreciated by all that the present recognised forestry methods will yield more timber per acre than would be secured were ordinary rubber plantation methods adopted for the growing of the trees. Rubber planters are not out for timber but for latex. They require their trees to reach a tappable stage at the earliest date possible—that puts a limit on the number of trees which can be allowed to develop per acre—they require the bark to renew satisfactorily after tapping, a matter which is affected by the spacing of the trees—further, they want to harvest optimum crops per acre from a cost of harvesting point of view. The first points are certainly impossible under a strict forestry method of conducting an estate, while as to the matter of optimum crops it is very questionable whether the tapping of the much larger number of small trees, resulting from the forestry method, would give larger yields or cheaper costs of production, taking either a short or long view of the comparison, than would be secured from an estate raised under normal methods.

The remarks given below refer to costs of production and supervision:

Attention must now be turned to the other important factor mentioned above as affecting the marketing of the commodity at the cheapest cost possible and the maintenance of an estate in such a condition that it will continue to be a cheap producer, i.e. the organisation of the estate on such lines that the most economical working can be secured. Under this heading the most important item is labour: the securing of it, the holding of it and the supervision of its work. It is estimated that labour charges on an European controlled estate total to about 45 per cent of F.O.B. costs. In considering labour and costs therefore it should be kept in mind that any difficulties found on estates planted upon flat or undulating land and which adopt forestry methods will be greatly exaggerated on steep, hilly land under the same conditions. The planted area of the estate under dis-

cussion is of an extremely hilly nature. But whatever the lie of the land, the *unchecked* growth of heavy cover and rubber seedlings greatly increases the difficulties of both supervisors and tappers and on a hilly estate under forestry conditions it is impossible to know whether all trees have been tapped, how they have been tapped, and whether they are affected with mouldy rot and require treatment. It is thus impossible to keep a proper check on the quality of the tapping, on the rate of bark consumption and on the control of mouldy rot. The compulsory cessation of the tapping of certain trees through this disease naturally has interfered with the proper carrying out of the tapping, while the tapping of trees affected by mouldy rot by careless tappers has only helped the disease further. Under such conditions as these it will be appreciated that it is impossible to get the best yields from the estate. In walking round a hilly estate which has adopted forestry methods the supervisor can see but relatively few trees of a tapper's task and much of the work has to be "taken as read".

Concluding Remarks

With reference to method of reducing costs of production by tapping a much larger number of smaller girthed trees, it may be remarked that such a state of affairs would approximate to "kampong" conditions, where usually a large number of comparatively small-girthed trees per acre have to be tapped. As pointed out already, labour charges on European estates are a most important item and it is obviously uneconomical if a coolie is bringing in five to seven pounds of dry rubber per task (a high figure for kampong holdings), instead of fifteen to twenty-four pounds per coolie on normal or good-yielding European estates. The kampong owners can usually carry on their tapping on the "bagi dua" system, i.e. share-and-share-alike system, whereby the owner and the tapping coolie or coolies, divide the proceeds of the sale of the rubber equally. In connection with the adoption of forestry methods, the question of kampong versus European estate methods has often arisen and the view that European estates could learn much regarding economical working has been often expressed. The writer's view is that the question does not arise because the situation is so very different in the two cases that they are not comparable. European estates of any sizable area demand a settled labour force, and the tapping coolie is the pre-eminent factor; after each tapping-round he must produce his economical yield quota and the number of trees to be tapped in a task is seldom above three hundred. But to obtain anything approaching the amount of rubber recognised as the economical yield quota on European estates, under kampong conditions, the coolies' task would have to include some 500-600 trees. These would prove poor

yielders, since they are usually thin-stemmed, hard-barked and comparatively difficult to tap. While a high yield per acre per annum may be obtained on a closely planted area, the tapping of the trees and collection of the latex could be done only at greatly enhanced prices.

Thus far the main consideration has been the dangers arising from methods which allow free development of natural undergrowth in mature rubber areas, and of this the interested reader can have no doubt. The writer has reiterated constantly that the system of allowing unrestricted freedom of natural undergrowths, coupled with selective weeding, would result in the appearance of objectional features, and the following quotation is extracted from the report of a prominent rubber company which held a meeting on December 19th, 1934:

> There is not much to chronicle about the working of the estates. Like all others, we have had our successes and our vicissitudes; good growth here, disappointing there; too few weeds in one place, too many for comfort in another, for while we are faithful to the doctrine of selective weeding, we have had to learn by experience that *a too generous enthusiasm in the practice of it may entail the necessity of counter measures of an energetic kind.* On the whole, we are very well pleased with the year's work.

There are perfectly sound reasons for severe criticism of forestry methods "carried to full measure", to use Dr. Whitford's words. The possibility of the repopulation of open spaces by the development of self-sown seedlings has been referred to already, but the present writer had further remarks to make before restriction became an established fact, and these cannot be applied with the same cogency under restriction conditions. But they may still be of interest because of possible future developments. The suggestions made by the advocates of forestry methods for the repopulation of open spaces or increasing the stand per acre by encouraging the growth of self-sown seedlings, seems likely to be misdirected. The work of the past ten years on the improvement of planting material is only just beginning to bear fruit, and in the next few years evidence will probably be forthcoming which will prove that the soundest economical proposition will be to adopt all possible measures to improve soil fertility in old rubber areas; this treatment is suggested with a view towards complete repopulation with superior material. Any attempt to bolster up inferior plantings with a sprinkling of high-grade material by using the self-sown seedling plants as stocks for bud-grafting purposes), which can only attain maturity very slowly under conditions of severe competition, should be abandoned. The adoption of *con-*

trolled forestry methods in any area, so improving the soil in readiness for the time when systematic replanting with high-grade material can be undertaken, seems to offer valuable possibilities.

In the final remarks, attention will be directed to the good points in the forestry system. Where the undergrowth is controlled so that growth in height is not allowed to exceed twelve to eighteen inches, substantial benefits may be derived in areas from which mouldy-rot disease is absent. But in areas subject to mouldy rot, or any other tapping-panel disease, the undergrowth must be cut back as near to soil-level as possible, if spread of the fungi and material damage to the trees is to be avoided. It will be generally agreed that controlled forestry methods definitely provide a useful means for the maintenance of soil fertility or for the improvement of soils which have declined in fertility owing to clean weeding and other cultivation methods. But until methods of disease control have advanced sufficiently to ensure the maintenance of health in the trees, necessary for continuous systematic tapping, there is grave risk of the failure of the system on economic grounds, viz. the profitable collection of the crop.

APPENDIX

LIST OF FUNGI RECORDED ON RUBBER TREES IN MALAYA

In his 1911 edition, entitled *The Physiology and Diseases of Hevea brasiliensis*, Petch gives a list of "Other Fungi on Hevea", and states that most of them were only saprophytic. He added the following observation, that "any mycologist who cared to devote the time to examining dead leaves, stems, etc., of *Hevea* would be able to extend this list tenfold, but *no useful purpose* would be served by doing so, because the majority of the fungi found on dead *Hevea* are quite harmless". This statement, made by a competent systematic worker, evidently escaped the notice of Baker, who published an article in 1919 recording the collections of fungi made on *Hevea* during an earlier visit to Malaya. This article was decidedly alarmist and provoked a rejoinder from Belgrave, which provided the proper perspective towards collections of saprophytic fungi found on dead parts of *Hevea*. Lists of fungi are doubtless of interest, and if opportunity permits it is desirable that the preparation of such lists should be undertaken. While admitting the desirability of obtaining a complete list of fungi growing on rubber trees, the writer would like to emphasise his view that the matter is purely one of secondary importance, and no good will result by exaggerating this aspect of phytopathological work.

The list following includes only those species which, as far as the writer is aware, have definitely been recorded from Malaya. A list of fungi is unlikely to prove of interest to anyone other than pathological workers, and if information is required regarding fungi on *Hevea* in other parts of the world, reference should be made to Weir's compilation in the publication issued as Bulletin No. 1380, United States Department of Agriculture, May 1926, entitled *A Pathological Survey of the Para Rubber Tree (Hevea brasiliensis) in the Amazon Valley*. Weir gives a comprehensive world list of fungi recorded on *Hevea*, and useful notes in connection with the more important species which cause diseases. The records in this book were made by Baker, Chipp and Weir ; Baker's and Weir's records are designated by B and W respectively ; the remainder, unmarked, are from Chipp's account. The fungi listed in Petch's 1911 edition, which are not mentioned in this list, are added at the end.

The following notes on three of the species included in the list are furnished through the good offices of Miss E. M. Wakefield:

Daedalea repanda, Pers.—The correct name is *Lenzites palisoti*, Fr. It is also known as *L. repanda*, Fr. and has many other synonyms.

Poria bracei.—I have not found the authority for this species and presume it to be an unpublished name. (This species is referred

to by Weir, but he gives no authority in the particular report consulted.)

Trametes ostreiformis.—Almost certainly intended for *Polyporus ostreiformis*, Berk. (The generic name, *Trametes*, is used in an article by Weir, but here again no authority was given.)

PHYCOMYCETES

Peronosporaceae

Phytophthora faberi, Maub.
Phytophthora sp.

ASCOMYCETES

Monascaceae

Monascus heterosporus, Schr.

Hysteriaceae

Lembosia glonioidea, Sacc. [B]
Hysterium heveanum, Sacc. [B]

Perisporiaceae

Apiosporium atrum, Mass.
Limacinia javanica, Sacc.

Microthyriaceae

Asterina tenuissima, Petch.

Hypocreaceae

Nectria diversispora, Petch.
Nectria sanguinea, Fr.
Pleonectria heveana, Sacc. [B & W]
Sphaerostilbe repens, B. & Br.
Megalonectria pseudotricha, Speg.

Cucurbitariaceae

Neotrotteria pulchella, Sacc. [B]

Mycosphaerellaceae

Sphaerella heveana, Sacc. [B]

Pleosporaceae

Didymella oligospora, Sacc. [B]

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Eutypa ludibunda, Sacc. [B]
Peroneutypa heteracanthoides, Sacc. [B]
Cryptovalsa microspora, Sacc. [B]
Thyridaria tarda, Banc.

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Diatrype chlorosarca, B. & Br. [W]

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Nummularia pithodes (B. & Br.), Petch.
Nummularia punctulata, Sacc.
Nummularia repandoides, Fuck., var. *singaporensis*, Sacc., var. nov. [B]
Ustulina zonata (Lév.), Sacc.
Daldinia concentrica, Ces. & De Not., var. *escholzii*, Ehrenb. [B & W]
Kretschmaria botrytis, Lloyd.
Xylaria cynoglossa, Cke.
Xylaria deserticola, Speg.
Xylaria multiplex (Kunze & Fr.), B. & C. [W]
Xylaria obovata, Berk. [W]
Xylaria plebeia, Ces. [W]
Xylaria scopiformis, Mont., var. *heveana*, Sacc. [B]
Xylaria tuberiformis, Berk. [B]

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Auricula polytricha (Mont.), Sacc. [W]
Septobasidium bogoriense, Pat. [W]
Septobasidium fumigatum, Burt. [W]
Septobasidium retiforme (B. & C.), Pat. [W]

Dacromycetaceae

Calocera stricta, Fr.

Thelephoraceae

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Corticium javanicum, Zimm.
Corticium salmonicolor, B. & Br.
Stereum cuneiforme, Lloyd.
Cyphella heveae, Mass.
Hymenochaete noxia, Berk.
Helicobasidium mompa, Tanaka.

Hydnaceae

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Lopharia mirabilis, (B. & Br.), Pat.

Polyporaceae

Daedalea repanda, Pers. [W]
Poria bracei. [W]
Poria hypobrunnea, Petch. [W]
Poria hypolateritia, Berk.
Poria porphyrophaea, Bres. [W]
Fomes lignosus, Kl.
Fomes pseudo-ferreus, Wakef.
Polyporus grammocephalus, Berk. [B]
Polyporus hirsutus, Pers. [B]

Polyporus rugulosus, Jungh. [B]
Polyporus williamsii, Murr. [B]
Polystictus flavus, Jungh. [B & W]
Polystictus occidentalis, Kl.
Polystictus sanguineus, Fr. [W]
Trametes corrugata, Bres. [W]
Trametes lachnei, Berk. [B]
Trametes ostreiformis, Berk. [W]
Trametes persoonii, Mont., forma *resupinata*.
Lenzites repanda, Pers.
Hexagonia cervino-plumbea, Jungh.
Hexagonia pulchella, Lev. [B & W]
Hexagonia tenuis, Hook. [W]
Hexagonia thwaitesii, Berk.
Favolus spathulatus, Jungh.

Agaricaceae

Lentinus lecomtei, Fr.
Lentinus leucochrous, Lév. [B]
Schizophyllum commune, Fr. [W]
Marasmius rotalis, B. & Br.

FUNGI IMPERFECTI

Sphaerioidaceae

Phyllosticta heveae, Zimm.
Phyllosticta ramicola, Petch.
Sphaeronema sp.
Diplodia rapax, Mass.
Botryodiplodia theobromae, Pat.

Melanconiaceae

Gloeosporium albo-rubrum, Petch.
Cephalasporium sp.
Eurotium candidum, Speg.
Sterigmatocystis sp.
Oospora gilva, Berk., is *Monilia carbonaria*, Cke., and probably is the imperfect form of *Neurospora sitophila*.
Penicillium maculans, Sharples.
Trichoderma koningii, Oud. & Koenig.

Dematiaceae

Helminthosporium heveae, Petch.
Spondylocladium maculans, Banc.

Stilbaceae

Echinodia theobromae, Pat.
Stilbella heveae, Zimm.
Stilbum cinnabarinum (Mont.), Lind. [W]

The following records are taken from the list given in Petch's 1911 edition. As several species are recorded from Brazil only, the country of origin is indicated. A few remarks of interest are included in cases where Petch indicates that more than a single name has been attached to the same fungus.

ASCOMYCETES

Nummularia pithodes (B. & Br.), Petch = *Diatrype pithodes*, B. & Br. = *Eutypa caulivora*, Mass.

Diaporthe heveae, Petch. Found only on one occasion in Ceylon.

Parodiella melioloides (B. & C.), Wint. On some species of *Hevea*, but whether *H. brasiliensis* or not, is not stated. Brazil.

Ophiobolus heveae, P. Henn. Same remark applies as for *P. melioloides* above. Brazil.

Nectria coffeicola, Zimm.

Calonectria cremea, Zimm. Probably identical with *Calonectria flavida*, Mass.

Phyllacora huberii, P. Henn. From Para.

Dothidella ulei, P. Henn. From Rio Jurua.

Tryblidiella leprieurii (Mont.), Sacc. From Ceylon. The finding of this species in Ceylon on dead branches of *H. brasiliensis* is of interest in so far as the species *Tryblidiella rufula*, Sacc., has been recorded from Singapore, but not specifically on *H. brasiliensis*.

BASIDIOMYCETES

Pleurotus augustatus, B. & Br. Ceylon.

Poria vincta, Berk. Ceylon.

Hexagonia discopoda, Pat. & Har. Ceylon.

Heterochaete tenuicola (Lév.), Pat. Ceylon.

FUNGI IMPERFECTI

Sphaerioidaceae

Phoma heveae, Petch. Ceylon.

Aposphaeria ulei, P. Henn. Brazil.

Sphaeronema album, Petch. Ceylon.

Ciliospora gelatinosa, Zimm. Ceylon.

Meianconiaceae

Gloeosporium brunneum, Petch, probably = *Gloeosporium heveae*, Petch.

Gloeosporium elasticae, Cooke & Massee, probably = *Colletotrichum ficus*, Koorders.

Colletotrichum heveae, Petch. Ceylon.

Pestalozzia palmarum, Cooke. Originally found on coco-nut leaves ; since found on Tea, Hevea, etc., but generally recorded under the name of *Pestalozzia guepini*, Desm.

Hyphomycetae

Periconia pycnospora, Fres. Ceylon.

Allescheriella uredinoides, P. Henn. Brazil.

Ceratosporium productum, Petch. Ceylon.

It seems desirable to stress that the names given and the authorities cited in this list of fungi are copied from Baker's, Weir's and Chipp's records; apart from excluding capitals for specific names, no alterations have been made. The list has been submitted to the Imperial Mycological Institute, and the authorities there, in collaboration with Miss E. M. Wakefield, have pointed out a few synonyms, made a few corrections in spelling and cited the authorities for *Polypore* names as accepted at the present date. These latter are given below, followed by the suggested changes. Also, I was informed that the specific names written for printing in *The Review of Applied Mycology* are spelt without capitals, and this seems a good example to follow for the purpose of this book, both in the text and the list of fungi.

POLYPORACEAE

Polyporous hirsutus, Pers. = *Polystictus hirsutus* (Wart.), Fr.
Polyporous rugulosus, Jungh. = *Polyporous rugulosus*, Lév.
Polyporous williamsii (Murr.).
Polystictus flavus, Jungh. = *Irpex flavus*, Kl.
Polystictus occidentalis, Kl. = *Polystictus occidentalis* (Kl.), Fr.
Polystictus sanguineus, Fr. = *Polystictus sanguineus* (L.), Fr.
Trametes corrugata, Bres. = *Trametes corrugata* (Pers.), Bresad.
Trametes lachnei, Berk., mistake for *Trametes lactinea*, Berk.
Trametes persooni, Mont. = *Trametes corrugata* (Pers.), Bresad.
Lenzites repanda, Pers. = *Lenzites repanda* (Pers.), Fr.
Hexagonia cervino-plumbea, Jungh. = *Hexagonia cervino-plumbea* (Jungh.), Lév.
Hexagonia tenuis, Hook. = *Hexagonia tenuis* (Hook.), Fr.
Favolus spathulatus, Jungh. = *Favolus spathulatus* (Jungh.), Bresad.

Nectria diversispora, Petch. } = Synonyms for
Nectria coffeicola, Zimm. } *Hypomyces ipomoeae* (Halst.), Wr.
Auricula polytricha (Mont.), Sacc., should be *Auricularia polytricha* (Mont.), Sacc.
Stilbum cinnabarinum (Mont.), Lind., should be *Stilbella cinnabarina* (Mont.), Lind.
Trichoderma koningii, Oud. and Koenig., should be *Trichoderma koningi*, Oud.

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BAKER, C. F., 1919. "Hevea versus Fungi", *Gards. Bull.* S.S. vol. 11, 4, p. 109.
CHIPP, T. F., 1919. "The Fungus Flora of *Hevea brasiliensis*", *Gards. Bull.* S.S. vol. 11, 5, p. 186.
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WEIR, J. R., 1928. *Ann. Rep. Path. Div. Rub. Res. Inst. of Mal.* p. 70.

GLOSSARY

Acervuli, small clusters, specially applied to clusters of fungus spores appearing on bark or leaves.

Acervulus (sing.), a little heap.

Ascocarp, the sporocarp of Ascomycetes producing asci and ascospores.

Ascus (sing.), *asci* (pl.), a large sack-like cell, usually the swollen end of a hyphal branch of the ascocarp, in which eight spores are normally developed.

Ascospores, spores produced in an ascus.

Basidium (sing.), *basidia* (pl.), the spore mother-cells in Basidiomycetes, having little pegs from which spores are abstricted or thrown off.

Cambial layer, the layer of cambium or formative tissue in stems during active growth.

Cambium, a layer of nascent tissue between the wood and the bast, adding new elements to both.

Caulicolous, applied to fungi which live on stems.

Chlamydospores, a spore having a very thick membrane.

Chloroplasts, the plastids or granules of protoplasm which are of a green colour.

Conidia, the same as brood cells, i.e. propagative cells asexually produced and separating from the plant.

Conidiophores, organs carrying conidia or spores, borne externally, as in the large majority of Fungi Imperfecti.

Coremia, fasciated forms of fructifications of certain fungi, e.g. *Stilbum* spp.

Cuticle, the outermost skin or pellicle covering the epidermis.

Cystids, large, one-celled, sometimes inflated bodies, projecting beyond the basidia and paraphyses of the hymenium in the *cap* of Agarics, e.g. *Marasmius* spp.

Dicotyledons, plants distinguished by the possession of two cotyledons or seed lobes, as contrasted with the single-seed lobe characteristic of Monocotyledons. Nearly all the flowering plants are comprised in these two classes.

Endoconidia, a conidium formed *within* the hyphae and extruded therefrom.

Endogenously, produced within another body, originating usually in a deep-seated position.

Epidermis, a layer of cells forming the true skin or covering of a plant, below the cuticle.

Epiphyte, a plant which grows on other plants but not parasitically; an air plant.

Globose, nearly spherical.

Gymnosperms, the modern order of naked-ovuled plants, e.g. Conifers.

Haustorium, a sucker, i.e. absorbing organ of parasitic plants, such as mistletoes.

Hyaline, colourless or translucent.

Hypha (sing.), *hyphae* (pl.), structural elements of the fungi; cylindric thread-like branched bodies developing by apical growth and usually septate.

Hypocotyl, the axis of an embryo below the cotyledons.

Kampong, Malay term, usually applied to gardens surrounding habitations occupied by Malays.

Meristematic, nascent tissue, such as cambium, capable of being transformed into special forms of tissue.

Mesophyll, the inner parenchyma of a leaf, the whole interior ground tissue of the leaf-blade between the upper and lower epidermis.

Monocotyledons, plants with a single-seed lobe; as in grasses and palms; in contrast to Dicotyledons (*q.v.*).

Oospore, the immediate product of fertilisation in an oosphere or egg cell.

Ostiole, the aperture through which spores escape from the perithecium in large numbers of Ascomycetes and Fungi Imperfecti.

Paraphyses, sterile filaments found in the perithecia of Ascomycetes and the pycnidia of some Fungi Imperfecti.

Perithecia, The fructification of Pyrenonyceles. Enclosed structures containing asci, which communicate with the exterior by a small opening.

Phloem, the bast elements of a vascular bundle; it is separated from the wood (xylem) by the cambium.

Phytophthoraceous, refers to fungi belonging to the orders *Phytophthoraceae* and *Pythiaceae* collectively.

Pileus, the cap of mushroom-like fungi which bears the spore-producing layer, i.e. the hymenium.

Primordial, first in order of appearance.

Primordial knob, term used to denote the earliest appearance of fructifications in polyporous (*Polyporaceae*) fungi such as *Ganoderma*, etc.

Resupinate, upside down or apparently so; when the spore-producing layer of a fungus, usually on the lower side, appears uppermost.

Resting spores, spores, usually with a thick integument, needing a period of rest before germinating, usually passing through a dry or wintering season in a dormant state.

Rhizomorph, a root-like branched strand of mycelial hyphae.

Root cap, large cells which form a cap-like protective covering for the smaller tender cells of the growing point of a rootlet.

Root hairs, slender outgrowths from the cells of the outermost layer of a root ; the latter corresponds to the epidermis of the aerial portions. This layer in roots is termed the *piliferous layer*, i.e. the layer producing hairs, from the newly formed portions of the roots.

Sieve plates, pierced plates on the transverse or lateral walls of sieve-tubes, covered on both sides by callus.

Sporangium, a sac endogenously producing spores.

Sporocarp, a many-celled body resulting from a sexual act and serving for the formation of spores.

Stoma (sing.), *stomata* (pl.), a breathing pore or aperture in the epidermis surrounded by two guard cells and leading into an inter-cellular space communicating with the internal tissues of the leaves.

Stone cells, individual cells which have become hardened by secondary deposits of lignin.

Tylose, a cell intruding into a duct; usually into the water-conducting vessels and blocking them up.

Vessels, ducts or articulated tubes rendered continuous by the more or less complete absorption of the intervening transverse walls.

Zoosporangium, a sporangium which produces zoospores or free swimming spores.

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THE END

Printed in Great Britain by R. & R. Clark, Limited, *Edinburgh*.